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NON-CONVENTIONAL SOIL TILLAGE SYSTEMS IN WINTER BARLEY AND SOYBEAN PRODUCTION

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Abstract. *The paper presents results of the two-year experiment in winter barley (*Hordeum vulgare *L.) and soybean (*Glycine max *L.) production. Short-term study of non-conventional soil tillage systems was conducted at the experimental field near Staro Petrovo Selo (45° 10' N, 17° 30' E) on Hypogley-vertic type of soil and semi humid climate conditions. The tillage systems and implements used were: CT – mouldboard plough, disc harrow, seed-bed implement, drill, RT 1 - chisel plough, disc harrow, seed-bed implement, drill, RT 2 - chisel plough, rotary harrow integrated with seed drill, RT 3 - mouldboard plough, rotary harrow integrated with seed drill. The highest average yields were obtained by RT 3 in barley production (4.42 t ha^{-1}) and RT 1 system in soybean (3.78 t ha^{-1}) production. The greatest energy and labour savings in soil tillage, among the lowest total cost of production, were achieved by RT 2 system, but due to the significantly lower yields this system has not proved adequate for soybean production, while it could be recommend in barley production due to the highest productivity accompanied with high yields and economic efficiency. The highest economic efficiency of barley production has shown RT 3 system (coefficient of 1.75), while in soybean production the most profitable system was RT 1 (coefficient of 2.16). Regarding the choice of tillage systems, assuming uniform level of yields, the advantage should be given to systems with lower level of tillage intensity, not only to reduce costs but also because of the possibility of simpler production organization due to less machine and labour requirement.*

Key words: *soil tillage, energy consumption, production costs, economic efficiency.*

1. INTRODUCTION

Soil tillage aims to create favourable conditions for seed germination and plant growth and is considered an indispensable part of arable crop production. The intensification of tillage, along with fertilization, crop protection and selection, has enabled a significant increase in yields, but also caused soil degradation, increased risk of erosion and rise of production costs. Greatest possibility for production rationalization offers tillage reduction, mainly by substitution of mouldboard ploughing as most energy and time-demanding task with conservation tillage systems.

Winter barley (*Hordeum vulgare* L.) and soybean (*Glycine max* L.) are important arable crops largely represented in the crop rotation on arable areas in Croatia. The mainly utilised soil tillage system in barley and soybean production, among other arable crops, is conventional system based on mouldboard ploughing as primary tillage operation, followed with secondary tillage performed by disc harrow and seed-bed implement. The long term application of conventional tillage showed significant economic and environmental drawbacks. From an economic point of view, disadvantages of conventional tillage systems are high energy and labour, large investment and maintenance costs of machinery, and ultimately higher costs of crop production. According to some European researches conventional tillage system requires 434 kWh ha^{-1} of energy and 4.1 h ha^{-1} human-machine work [1], [2]. In contrast, reduced tillage systems can bring about 30% -50% savings of the energy and human-machine work, and direct sowing as much as 70%, compared to conventional tillage. From an ecological point of view, disadvantages of conventional tillage systems are increased soil compaction caused by excessive number of machinery passes, systematic reduction of soil organic matter (humus content) as a result of intensive and frequent tillage and the greater the susceptibility to soil erosion [3]. A significant CO_2 emissions from the combustion of large amounts of fuel consumed in the intensive tillage is also an environmental issue [4]. Stroppel [5] reported that by the end of the last century about 85% of the arable land of central Europe was under conventional tillage systems. The implementation of reduced tillage systems has not significantly increased to date, and it is estimated that there are still less than 10% [6]. The world leading agricultures in substitution of conventional soil tillage systems with different variations of the reduced tillage and direct sowing are United States and Canada in North America and Brazil, Argentina, Uruguay and Paraguay on the South, where conservation tillage and no-tillage systems applied to more than half of total arable crop area [7]. Despite the mentioned trends, it is estimated that over 90 % of the fields in Croatia are still being tilled with the conventional tillage system [8].

Previous studies suggest that reduced tillage is favourable for high density crops such as winter wheat, spring barley and canola, while much worse option for spring row crops such as corn and soybeans [9], [10], [11], [12]. While some authors [13] have noticed a decrease of yield of spring barley with the degree of tillage reduction (14% lower yield at a reduced tillage and 27% lower in direct drilling), others claim that there is no significant difference in realized yields between different tillage systems [14]. Reduction of production costs by applying some of the reduced tillage systems, in conditions where yields were not significantly reduced due to lower tillage intensity, enables a lower profitability threshold [15], [16], [17].

2. MATERIAL AND METHODS

The experiment was performed at agricultural company "PK Nova Gradiška" in village Staro Petrovo Selo, located 150 km south-east from Zagreb (45° 10' N, 17° 30' E). Experimental field was consisted of 12 plots with dimension length 250 m x width 56 m each, organized as randomized blocks with three replications. The tillage with different systems was performed on the Hypogley-vertic type of soil [18] and its texture in ploughed layer belongs to the silty clay loam (Table 1).

Table 1. Soil particle size distribution

Depth (cm)	Particle size				Texture[1]
	0.2-2 μm (%)	0.05-0.2 μm (%)	0.002-0.05 μm (%)	<0.002 μm (%)	
0-30	16.0	28.0	22.0	34. 0	SiCL
30-60	13.0	32.0	26.0	29.0	SiCL-SiL
60-90	13.0	31.0	28.0	28.0	SiCL

[1)] SiCL = Silty clay loam, SiL = Silty loam

Implements, which were included in different tillage systems, are as follows:
1. Conventional tillage – mouldboard plough, disc harrow, multitiller, drill (CT);
2. Conservation tillage 1 - chisel plough, disc harrow, multitiller, drill (RT1);
3. Conservation tillage 2 - chisel plough, rotary harrow + drill (RT2);
4. Conservation tillage 3 - mouldboard plough, rotary harrow + drill (RT3).

Mouldboard plough used in tillage systems CT and RT3 was Kuhn Multimaster 151 with four bodies, disc harrow was Kuhn Discover XM 44/660, multitiller Lemken Korund 750L, and seed drill Tive 2000. Chisel plough used in RT1 and RT2 was Agram GeoDec SVD6. In conservation tillage systems RT2 and RT3 an integrated implement Kuhn Integra 3000 was used, consisted of rotary harrow and seed drill.

Energy requirement of each tillage system was determined based on the tractor's fuel consumption. The amount of fuel consumed was measured for each implement (tillage and sowing) on every single plot. Specific energy consumption is calculated based on the energy equivalent of 38.7 MJ L^{-1} for diesel fuel used. In this experiment 4WD tractor with engine power of 136 kW was used. The working width of the tillage implements was chosen according to the pulling capacity of the tractor. The labour requirement was determined by measuring the time for finishing single tillage operation at each plot of the known area (14,000.00 m^2). The yields were determined by weighing grain mass of each harvested plot, and recalculated according to grain moisture content in storage conditions afterwards. Fertilization and crop protection was uniform in all tillage, determined by crop specific requirements.

Schedule of the field operations (tillage, fertilizing, sowing, crop protection, harvesting) and soil moisture content at the moment of tillage are shown in Table 2. On the experimental field previous crop was winter wheat. Working conditions regarding soil moisture content, soil compaction and post-harvest residues at the beginning of experiment were equal for all tillage treatments.

Table 2. Date of field operations and application rates

Description	Winter barley	Soybean
Tillage & Sowing		
Primary tillage	1st November 2009	August 26th 2010
Soil moisture (%) at 5; 15; 30 cm depth	18.8; 28.7; 33.2	16.2; 44.2; 44.4
Secondary tillage	15th October 2009	April 21st 2011
Soil moisture (%) at 5; 15; 30 cm depth	30.1; 29.7; 31.0	23.9; 45.9; 43.7
Sowing date	15th October 2009	April 21st 2011
Crop-cultivar (kg ha^{-1})	Mombasa (210)	Podravka (120)
Fertilizing		
Application date	14th October 2009	March 29th 2011
Fertilizer-rate (kg ha^{-1})	Urea 46% (100)	NPK 0:20:30 (400)
Application date	2nd March 2010	April 20th 20011
Fertilizer-rate (kg ha^{-1})	CAN 27% (150)	Urea 46% (100)
Application date		June 7th 2011
Fertilizer-rate (kg ha^{-1})		CAN 27% (100)
Crop protection		
Application date	27th November 2009	April 22nd 2011
Chemical-rate (l ha^{-1})	cyhalothrin (0.15) triasulfuron (45 g ha^{-1})	metribuzin (0.70) dimetenamid (1.30)
Application date	15th April 2010	May 10th 2011
Chemical-rate (l ha^{-1})	azoxistrobin (0.033)	fomesafen (0.75) tifensulfuron-metil (0.008)
Application date	21th April 2010	June 4th 2011
Chemical-rate (l ha^{-1})	epoxichonazol + crezoxim-metil (0.8)	propakizafop (1.00) bentazon (2.5)
Application date	12th May 2010	April 22nd 2011
Chemical-rate (l ha^{-1})	prothioconazole (0.9)	metribuzin (0.70) dimetenamid (1.30)
Harvest		
Harvesting date	12th July 2010	September 16th 2011

Economic efficiency of different soil tillage systems was calculated based on the natural indicators of barley and soybean production (energy consumptions, labour requirement, raw materials, yields). Statistical analysis of data for all research indicators was done with computer program SAS [19] using analysis of variance (ANOVA). The significance of differences between the observed parameters were indicated by F-test at the level of probability $p = 0.05$.

3. RESULTS AND DISCUSSION

3.1. Yield

In winter barley production the greatest average yield of 4.42 t ha^{-1} was achieved by RT3 tillage system followed by CT with average yield of 4.14 t ha^{-1} and RT2 with 4.04 t ha^{-1}. The lowest average yield was obtained with RT1 system 3.71 t ha^{-1}. According to ANOVA, differences of average winter barley yields obtained by different soil tillage systems were statistically significant between RT3 and RT1, at probability level of $p<0.05$. CT and RT2 yields were not significantly different to other tillage systems.

In the cultivation of soybeans the highest average yield of 3.78 t ha^{-1} was obtained with reduced tillage RT1, which is 15% higher than the yield recorded on a conventional tillage system (3.28 t ha^{-1}). The lowest average yield of soybeans 2.76 t ha^{-1}, or 19% less than conventional system was recorded in RT2. Analysis of variance revealed significant differences in average yields between RT1 and RT2 on the $p <0.05$ level. At variant RT3 average yield was slightly lower than in the variant with conventional tillage and that difference was not statistically significant.

Along with noticed occurrence of yield instability with a reduction of soil tillage [20], yields may also be susceptible to seasonal climate deviations [21], [22].

3.2. Energy and labour requirement

The conventional tillage system (CT) was expectedly the greatest fuel consumer (Table 3). In winter barley production the greatest fuel consumption of 50.93 L ha^{-1} was recorded in conventional tillage system. RT3 system enabled 10.3% saving and RT2 20.1% saving of fuel compared to conventional tillage. The greatest energy saving per hectare (35.1%) in winter barley was obtained by RT1 system.

A total of 48.23 L ha^{-1} diesel fuel was spent in tillage and planting soybeans with conventional system wherein the mouldboard ploughing stands out as the most significant consumer with about 64% of total energy consumption. At variants with reduced soil tillage RT1 and RT2 were spent a third less fuel/energy in which the system RT1 points to 42.2% lower specific energy consumption (328.7 MJ t^{-1}) due to significantly higher yield compared to the conventional system.

Table 3. Energy and labour requirement of different soil tillage systems

	Winter barley				Soybean			
Tillage system	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	h t^{-1}	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	h t^{-1}
CT	**Average yield = 4.14 t ha^{-1} ab [(1)]**				**Average yield = 3.28 t ha^{-1} b**			
Mouldboard plough	33.4	312.3	1.21	0.29	31.12	367.0	1.35	0.41
Disc harrow	9.95	93.0	0.28	0.07	9.67	114.0	0.34	0.10
Multitiller	4.95	46.3	0.24	0.06	4.31	50.8	0.17	0.05
Seed drill	2.63	24.6	0.41	0.10	3.13	36.9	0.56	0.17
Total	**50.93**	**476.2**	**2.14**	**0.52**	**48.23**	**568.7**	**2.42**	**0.74**
RT 1	**Average yield = 3.71 t ha^{-1} b**				**Average yield = 3.78 t ha^{-1} a**			
Chisel plough	18.42	192.4	0.58	0.16	15.00	153.6	0.57	0.15
Disc harrow	7.03	73.4	0.26	0.07	9.67	99.0	0.34	0.09
Multitiller	4.95	51.7	0.24	0.06	4.31	44.1	0.17	0.04
Seed drill	2.63	27.5	0.41	0.11	3.13	32.0	0.56	0.15
Total	**33.03**	**344.9**	**1.49**	**0.40**	**32.11**	**328.7**	**1.64**	**0.43**
RT 2	**Average yield = 4.04 t ha^{-1} ab**				**Average yield = 2.76 t ha^{-1} c**			
Chisel plough	18.42	176.4	0.58	0.14	15.00	209.2	0.57	0.20
Rotary harrow + drill	22.26	213.2	0.78	0.19	17.04	237.6	0.61	0.22
Total	**40.68**	**389.6**	**1.36**	**0.34**	**32.04**	**446.8**	**1.18**	**0.42**
RT 3	**Average yield = 4.42 t ha^{-1} a**				**Average yield = 3.27 t ha^{-1} b**			
Mouldboard plough	28.86	252.9	1.23	0.28	31.12	368.6	1.35	0.41
Rotary harrow + drill	16.83	147.5	0.76	0.17	16.44	194.7	0.59	0.18
Total	**45.69**	**400.4**	**1.99**	**0.45**	**47.56**	**563.4**	**1.94**	**0.59**

[(1)] Different letters indicate significant ($p \leq 0.05$) differences

The highest productivity regarding labour requirement per hectare and ton of grain yield was achieved with RT2 tillage system in both winter barley and soybean production. Comparing the results with allegations by other authors [23], [24] larger deviations due to soil types, current conditions in the field, depth of tillage and implements used could be expected, but an increase in labour productivity with the degree of reduction of tillage is noticeable.

3.3. Economic analysis

Total costs include all the inputs (labour, machine costs, seed, fertiliser and plant protection chemicals) from soil tillage to harvest, including grain transport within field. Storage and handling costs were not taken into account since its great variability.

In both seasons CT system resulted in the highest costs with 546.00 € ha^{-1} (winter barley) and 790 € ha^{-1} (soybean) mainly due to great number of field operations and large amount of labour requirement (Table 4). In winter barley production the highest income was obtained with RT3 system and that variant also showed the best economic efficiency (coefficient 1.75). In soybean production the highest economic efficiency was achieved in RT1 system (coefficient 2.16) together with the highest income due to significantly higher yield compared to other tillage systems.

Similar to findings of other authors [25] [26] better economic effects were achieved principally with reduced tillage systems.

Table 4. Energy and labour requirement of different soil tillage systems

Tillage	Winter Barley				Soybean			
	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio
CT	875.00	564.00	311.00	1.55	1,394.00	790.00	604.00	1.76
RT 1	816.00	537.00	279.00	1.52	1,560.00	721.00	839.00	2.16
RT 2	862.00	496.00	366.00	1.74	1,225.00	703.00	522.00	1.74
RT 3	913.00	523.00	390.00	1.75	1,389.00	731.00	658.00	1.90

4. CONCLUSIONS

Summarizing the results together with previously acquired experience it could be concluded that the production of winter barley and soybean, as important arable crops largely represented in the crop rotation on arable areas in Croatia, has proven to be economically efficient at all variants of soil tillage.

Better economic results were achieved mainly with the reduced tillage systems as a result of higher yields and reduced production costs compared to conventional system. Thus, the best improvement of economic efficiency in the production of winter barley was 13% obtained with RT3 tillage system and 23% with RT1 system in soybean production. Although the reduction of soil tillage has shown a positive impact on the production costs, it was justified only if there has not led to significant yield reduction as was the case with RT1 tillage system in winter barley and RT2 in soybean production.

Conventional tillage system was expectedly the greatest energy and labour consumer. The greatest energy saving per hectare in winter barley production was obtained by RT1 system (35.1% less than CT) and in soybean 33.5% by RT 1 and RT2. The highest productivity regarding labour requirement per hectare and ton of grain yield was achieved with RT2 system in both winter barley and soybean production, but due to the significantly lower yields this system has not proved adequate for soybean production, while it could be recommend in barley production due to the highest productivity accompanied with high yields and economic efficiency.

As this short-term experiment showed that non-conventional tillage systems could be economically important tool to decrease production costs, in the preferred choice of soil tillage system, assuming uniform levels of yield, the advantage should be given to a system with lower level of tillage intensity, not only to reduce costs, but also because of the simpler production organization due to less machine and human labour requirement.

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Expert paper

RESULTS OF TESTING THE VARIOUS SOIL TILLAGE SYSTEMS IN THE PRODUCTION OF WINTER RYE AND MAIZE IN CENTRAL SERBIA

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Abstract. *In this paper there have been presented the results of two-year trials of different tillage systems, in the production of winter rye and maize. The trials have been performed in the agro-ecological conditions of central Serbia during the season 2010/2011. The field-lab tests have been conducted at two sites on the soil type Vertisol, referred to the assessment of quality of work, energy consumption and its impact on the yields in three different tillage systems in the production of rye and maize. The aim of this study was to determine the effects of different parameters of soil tillage, which would allow the proper selection of appropriate technology and technical systems and point out the advantages and disadvantages of applied systems of soil tillage. In the variant of conventional tillage (CT) it has been achieved the highest consumption of fuel, over than 60 L ha^{-1}, with the yield of winter rye of 2.110 kg ha^{-1}, while in the variant of reduced tillage (RT) it has been recorded the lowest fuel consumption, about 46.83 Lha^{-1} , and the highest yields of winter rye of 2.596kg ha^{-1}. The obtained results show that in the variant of reduced tillage, it has been achieved higher yields of rye and maize, with significantly lower energy consumption. By the reduced tillage system it has been achieved 33.35% lower fuel consumption, compared to the conventional tillage.*

Key words: *Tillage system, Fuel consumption, Rye, Maize, Yield.*

1. INTRODUCTION

Maize (*Zea mays L.*) and rye (*Secale cereale L.*) take an important place in agro-ecological conditions of central Serbia. Both crops are important for human, livestock, processing and pharmaceutical industries. Industrial processing of corn can provide over than 500 different products, and it is very important for obtaining bioethanol. Rye is an important agricultural crop for obtaining bread wheat, and contains sufficient amounts of vitamin A, B, E [14]. According [17] in Serbia 2011th maize has been planted on 1.262.000 ha in total, with an average yield of 5.1 t ha^{-1}. Rye has been sowed at 5.400 ha, and it has achieved an average yield of 2.1 t ha^{-1}. Technology of rye and maize production in central Serbia is based on different tillage and seedbed preparation in autumn and spring. Plowing is dominant in conventional tillage system, with addition of disc harrow treatment and seedbed preparation using a seed-beder. The result of inadequate tillage systems have significantly reduced yields with relatively high production costs. Many researchers have worked on a problems of different tillage systems. Significant changes in the production of maize production have been enabled by intensive production, replacing horse-drawn carts by powerful tractors, changes in methods and systems of farming and the introduction of hybrid seed production [2]. The technology of plowing is the most expensive, most complicated and slow in terms of organization with great fuel economy, and a environmentally very unfavorable [20]. Soil tillage is one of the basic operations in agricultural production aimed on creating the conditions in the soil root system has enough air, water and nutrients [3]. In conventional tillage after a plowing, often is the case that the fragmentation of soil aggregates and crop residues is being used disc harrow a few times. This operation has a significant impact on soil structure, increasing the risk of erosion, and energy consumption and production costs are higher [7]. Wrong choice of tillage systems poses a risk affecting the conservation of moisture, the yields and production costs [6]. Application of conventional tillage under intensive cultivation of crops and vegetables [4], requires a permanent initiative for improving the quality and appropriateness of technology and technical systems. According to [15] minimum tillage it should be considered as an alternative to conventional treatment, especially for planting of winter crops, taking into consideration natural fertility, storage capacity and implement the optimum planting period. Because the conventional systems have caused soil degradation in many countries, the technologies concerning the mechanization of agricultural practices must be adapted to the requirements, concerning soil and water protection, and soil conservation practices are necessary in the areas with more sensitive soils to degradation [18 Conservation tillage is becoming increasingly attractive to farmers because it involves lower production costs than conventional tillage systems, with higher yields and lower fuel consumption [19]. Minimum soil tillage systems have as main feature soil conservation, maintaining a proper balance between the soil organic matter and microorganisms activity improvement [16]. Experimenting with different tillage systems in maize and soybean production found that average maize yield on chisel plots was significantly ($p=0.05$) higher then with no tillage system[1]. The conventional tillage system is acceptable in the production year with moderate rainfall throughout the vegetation. Conservation tillage systems enables higher yields compared to conventional, even in years when precipitations during the growing season are moderate, when sunflower yields were higher than 8.6% and merchant maize than 9.9% [5]. Economical production of maize and fuel savings of 20 to 50 l ha^{-1} can be achieved, and the implementation of new systems and constructions of machines for tillage and sowing, which are based on the tools and cultivation by direct sowing. Conventional technology with rummaging plow in autumn tillage systems, fuel only in tillage and sowing was in the range of 30 to 60 L ha^{-1}, while reduced tillage with the use of disc harrow instead of plow, gained fuel savings in the range of 15 up to 20 l ha^{-1} [11,12]. The highest fuel consumption in the production of winter barley and maize was measured by conventional soil tillage (CT) and 56.07 l ha^{-1} in winter barley and 62.93 l ha^{-1} in maize. In reduced tillage (RT1) in winter barley consumption was 37.58 l ha^{-1}, and the reduced tillage (RT2) in maize 36.30 lha^{-1}. Energy savings ranged from 33 to 42%. In conventional soil tillage it has been measured 67.72 l ha^{-1}, whereas in reduced tillage fuel consumption reduced by 21.6% [8,9]. Each percentage reduction in cost and energy savings in the production of maize makes an important item, given that its presence in over 50% of arable land Serbia [13]. According to the same authors, in comparison to the conventional primary tillage by plow, changing technology of production (reduced tillage, direct seeding), it can be saved up to 46 l ha^{-1}. In conventional tillage systems in wheat production that is performed by harrows, plows and engine preparation and sowing consumes about 44.74 l ha^{-1} of fuel, and in conservation tillage consumes about 34.19 l ha^{-1}, which is the consumption reduction for 23,58 % [10].

2. MATERIAL AND METHODS

The impact of different tillage systems on the production of winter rye and maize were carried out during 2010/11 in agro-ecological conditions of central Serbia (near Kragujevac 44° 06 '00 "N, 20° 51' 00" E). The experiment has been conducted with Raša variety of winter rye and maize hybrid NS 640, and previous crops were maize and wheat. Research has been conducted on the soil type Vertisol (FAO classification). Size of experimental field was 8 hectares and it was divided into four plots (replications) for each tillage system with both cultures. The study included two tillage systems. The first tillage system applied has been conventional tillage (CT), which is the mostly spread tillage system in the agro ecological conditions of the Central Serbia. Within the frame of this tillage system, plowing by two furrow carried plowshare plow, at the average depth of 23.4cm, for maize and 16.1 cm for rye, than harrow the soil has been done with carried disc harrower with four batteries, and fine harrowing with a peg-tooth harrow. After that, sowing has been done. The other system has reduced tillage (RT), and within this tillage, first it has been done tillage with chisel plow, at the average depth of 22.8cm for maize and 12.3cm for rye. Then, it has been done harrow of the soil with carried disc harrower with four batteries, and a seedbed preparation with seedbeder. After that, sowing has been done. Chosen tools for soil tillage have been based on the strength and strain characteristics of the tractor. Retrieval of the tools has been performed by tractor of 46.5 kW (IMT 560).

The study included the evaluation of the quality of work of soil tillage depending on the applied tillage system, fuel consumption, achieved performance and the amount of winter rye and maize yields. The quality of soil aggregates in different tillage systems has been defining the representation of the different fractions of soil aggregate stability. Share of fractions has been determined my method of *Savinov*, the sampling has been done before sowing. Sampling has been done from a depth of 0-20 cm and analyzed in soil science laboratory by dry sieving on sieves of different diameters. Share of structural aggregates is shown in tables and expressed as a percentage. Fuel consumption has been determined by volumetric method, while the productivity of aggregates has been determined by chronometric method, based on a known working width in soil tillage. Fertilization was carried out in the same doses in all tillage systems. Yields were measured by diagonal plots and calculated on the entire experiment. Harvest of winter rye has been done by combine ZMAJ-135 in the first half of July, and the maize harvesting has been done with harvester ZMAJ- 223 in the second half of October. The experiment was conducted in completely random variations of the plan. Applied methodology can be stated as the standard for this problem which concerns the field laboratory testing and exploration of different tillage systems. The table 1 presents the basic data on the date of execution of tillage, fertilizer quantities that have been made, sowing and the time of harvest.

Table 1 Data of operation terms in winter rye and maize production

Description of the measure	Winter Rye 2010/2011.	Maize 2010/2011.
Soil preparation and sowing		
Basic soil processing	October 15th, 2010.	September 25th, 2010.
Soil moisture (%) on 0-20 cm depth	28.7	29.6
Additional processing	October 20th, 2010.	April 15th, 2011
Soil moisture (%) on 0-20 cm depth	31.5	26.9
Sowing time	October 25th, 2010.	April 17th, 2011.
Cultivar	Raša	NS 640
Applied fertilization		
Time of fertilizing and the amount of fertilizers	October 25th, 2010.	September 25th, 2010. manure 25 t ha^{-1}
	Manure 15 t ha^{-1} NPK 8:24:16 - 250 kg ha^{-1}	September 25th, 2010. manure 25 t ha^{-1}
		April 15, 2011. Urea 46% - 150 kg ha^{-1}
	March 6th, 2011. NPK 8:24:16 - 200 kg ha^{-1}	April 17th, 2011.NPK (15:15:15) 150 kg ha^{-1}
		June 10, 2011. CAN 25%- 150 kg ha^{-1}
Date of harvest	July 10th, 2011.	October 29th, 2011

In the table 2 it is presented the basic data on the technical characteristics of the tested machinery.

Table 2 Technical characteristics of the machinery

Indicators	Unit	Working tool						
		Two furrow plough IMT 756.20	Disc harrow Sava 24	Peg-tooth harrow IMT 611.4	Seed beder VogelNot L 210	Chisel plough CHP 150	Rye seed drill IMT 634.23	Maize drill OLT MSK 4
Number: • plough bodies • battery • working bodies • rows	/	2	4	4	21	5	23	4
Working width	cm	60	210	380	210	150	276	260-320
Working depth	cm	25	12	to 8	to 12	to 40	to 10	4-12
Mass	kg	251	420	227	360	360	501	480
Required power	kW	26	26-33	29	37	33	26	26-33

Values of average monthly air temperatures during experiments and sum of precipitations in comparison to perennial average are shown in graphs 1 and 2.

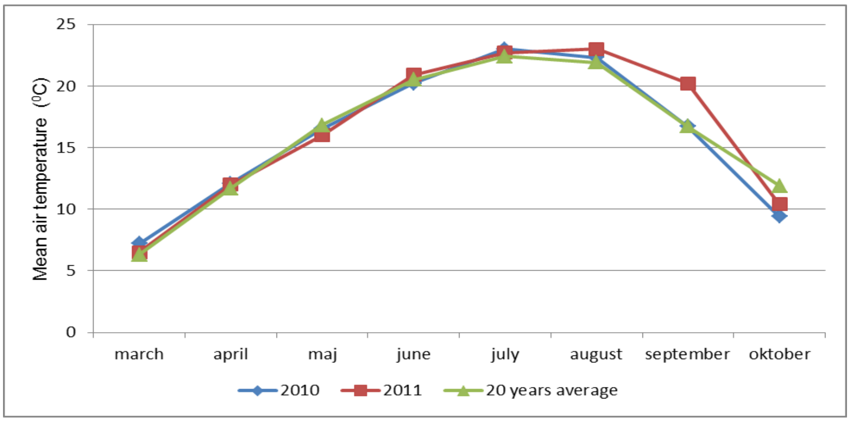

Fig.1 Mean air temperature during cropping period

Based on Graf 1 it can be noticed that the air temperature during the experiment from 2010 to 2011. Has been at the level of perennial average for the entire project area and did not significantly deviate.

When the total amount of precipitation is being considered (Graf. 2), significant differences were noted in relation to the perennial average. Deviations from the perennial average were higher in the 2010th year and particularly in May and July.

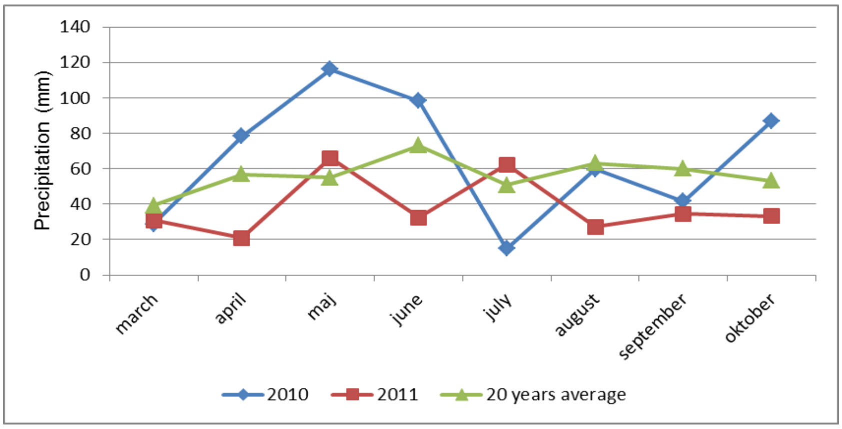

Fig.2 Precipitation during cropping period

3. Results and discussion

Table 3, shows the results of the examined tillage systems on soil quality in the production of winter rye and maize.

Table 3 The influence of tillage on the quality of soil preparation

Fraction of structural aggregates (mm)	Winter rye		Maize	
	Conventional tillage (CT)	Reduced tillage (RT)	Conventional tillage (CT)	Reduced tillage (RT)
	Fraction of structural aggregates (%)			
> 10	33.17	19.47	31.85	15.27
10 - 8	7.26	8.61	7.69	6.98
8 - 6	5.38	8.96	6.48	6.24
6 - 3	18.35	26.95	19.38	27.99
3 - 1.25	12.14	13.10	11.56	16.88
1.25 - 0.3	17.77	16.72	16.96	19.73
0.3 - 0.25	3.28	3.21	3.20	3.85
< 0.25	2.65	2.98	2.88	3.06
Total	100	100	100	100

Based on the results shown in table 3 it can be noted that the tillage system showed significant impact on the quality of soil preparation. In conventional soil tillage (CT) for winter rye recorded the highest content of macro aggregates (stable aggregates> 10 mm) in the amount of 33.17%. The content of aggregate size was 10-8 mm is 7.26%, while in aggregates of land the size of 8-6 mm were present from 5.38%. Content desired mezo aggregates (aggregates size of 6-3 mm) was significantly lower, so that was 18,35%, while the aggregate size of 3-1.25 mm were present from 12.14%. Microaggregates (in aggregates <0.25mm) were analyzed in this sample processing system represented with 2.65% (table 2). By applying the reduced soil tillage (RT) it has been obtained better soil preparation. Compared to conventional treatment, a significantly smaller proportion of macro-aggregates (> 10 mm) and 19.47%, while the measured significantly higher proportion mezoaggregate (in aggregates 6-3 mm) to 26.95%, while the content of the structural unit 3-1.25 mm was 13.10%.

A similar effect of soil tillage systems has been achieved in the processing of maize too. Thus, the in conventional tillage content of macro aggregate (> 10 mm) was 31.85%, and mezoaggregate (6-3mm) 19.38%. Reduced tillage (RT) obtained better soil preparation bearing in mind that the content of mezoaggregate (6-3mm) was 27.99%, and macro aggregates 15.27% (table 3).

Table 4 shows the results of fuel consumption outputs achieved and actual yield depending on the applied processing system. Based on the results shown in table 4, it can be noted that in the tested soil tillage systems measured different values of fuel consumption. In conventional soil tillage (CT) in the production of winter rye, had overall fuel consumption of 62.45 L ha^{-1}, while in the reduced soil tillage (RT) it has been measured the overall fuel consumption of 46.83 L ha^{-1}. Based on the obtained results it can be noted that in the reduced tillage systems, it is reached lower fuel consumption for 33.35%.

Testing the level of significance of the differences in terms of the amount of total fuel consumption with reduced system compared to conventional tillage system shows significant differences ($p< 0.05$).

Table 4 Fuel consumption, efficiency and yield depend on tillage systems

Tillage System	Winter rye 2010/2011			Maize 2010/2011		
Conventonal tillage (CT)	Average fuel consumption L ha^{-1}	Average efficiency ha h^{-1}	Operation speed km h^{-1}	Average fuel consumption L ha^{-1}	Average efficiency ha h^{-1}	Operation speed km h^{-1}
Plough	32.36	0.21	3.34	39.75	0.19	3.10
Disc harow	15.51	0.93	5.20	15.57	0.88	5.26
Peg-tooth harrow	7.15	1.66	5.48	7.34	1.69	5.53
Sowing	7.43	1.49	6.75	7.25	1.46	6.12
Total	62.45	4.29	/	69.91	4.22	/
Yield (kg ha^{-1})	2.110			4.738		
Reduced tillage (RT)						
Chisel plough	16.82	0.62	5.15	22.17	0.53	4.42
Disc harrow	15.53	0.95	5.33	15.58	0.97	5.44
Seed-bed preparing	7.35	0.96	5.39	7.76	0.99	5.56
Sowing	7.13	1.67	7.10	7.39	1.48	6.18
Total	46.83	4.20	/	52.90	3.97	/
Yield (kg ha^{-1})	2.596			5.884		

Selected system of cultivation had a significant impact on the amount of grain yields of winter rye, so that the conventional tillage (CT) grain yield of rye is 2.110 kg ha^{-1}, and with the reduced soil tillage 2.596 kg ha^{-1}, which represents an increase of yield of 23.10%. The differences were evaluated as significant ($p < 0.05$) (table 4).

A similar effect of tillage systems on fuel consumption was recorded in maize production. So in the conventional soil tillage (CT) it was the overall fuel consumption of 69.91 l ha^{-1}, and the reduced soil tillage (RT) 52.90 L ha^{-1} . The differences in terms of fuel consumption were evaluated as significant ($p < 0.05$), and in the reduced tillage system it has been measured the lower fuel consumption for 32.16%.

In conventional tillage systems (CT) maize yield was 4.738 kg ha^{-1}, and the in the reduced tillage systems (RT) 5.684 kg ha^{-1}, which means that there has been a higher yield of 19.97%. Differences in the amount of yields that have arise, and impact of the application of soil tillage systems were evaluated as significant ($p < 0.05$).

Similar results on the impact of tillage systems on energy consumption and amount of yields stated in his research by other authors [5, 7, 8, 9, 10, 11, 12, 16].

4. CONCLUSIONS

The investigation of the effects of different tillage systems in the production of winter rye and maize, it can be concluded as follows:

Selected system of tillage had a significant effect on the quality of soil preparation. In conventional soil tillage (CT) for winter rye it has been recorded the highest content of macro aggregates (stable aggregates > 10 mm) and to 33.17%, while the content of desired mezoaggregates (aggregates size of 6-3 mm) was significantly lower 18.35%.

By system of conservational or reduced tillage (RT) it has been obtained better soil preparation because a significantly lower proportion of macro-aggregates (> 10 mm) and 19.47%, while the measured significantly higher proportion mezoaggregates 26.95% . A similar impact has been recorded in maize crop as well.

In the conventional soil tillage (CT) in the production of winter rye the overall fuel consumption was 62.45 l ha^{-1}, while in the reduced soil tillage (RT) it has been measured the overall fuel consumption of 46.83 l ha^{-1}, which is lower fuel consumption of 33.35%. Test of the significance shows that the obtained differences are evaluated as significant ($p< 0.05$).

In the production of maize by conventional tillage (CT) it has been measured the overall fuel consumption of 69.91 l ha^{-1}, and with the conservational or reduced tillage (RT) 52.90 l ha^{-1}. The differences in terms of fuel consumption were evaluated as significant ($p< 0.05$) and with the reduced tillage it has been measured reduction of fuel consumption of 32.16%.

In conventional tillage (CT), the rye yield of 2.110 kg ha^{-1} have been achieved, and in the reduced tillage (RT) of 2.596 kg ha^{-1}, which is a yield increase of 23.10%. The differences were evaluated as significant ($p< 0.05$).

In conventional tillage systems (CT) , the yield of maize was 4.738 kg ha^{-1}, and in the reduced tillage system (RT) 5.684 kg ha^{-1}, which means that there has been a higher yield of 19.97%. Differences in the maize yields have been evaluated as significant.

The results indicate that in the variant of reduced tillage (RT) it have been achieved higher yields of rye and maize compared to conventional tillage system (CT), with significantly lower energy consumption. So RT system can successfully be applied in the production of winter rye and maize in the investigated region.

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Original scientific paper

INFLUENCE OF COLOR SHADE NET ON THE CLIMATE CONDITION IN PEPPER PRODUCTION

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Abstract:. *The photoselective netting concept was studied in bell pepper (Capsicum annuum 'Cameleon') cultivation in the south Serbia (Aleksinac) under high solar radiation, using commercial cultivation practices, under four different colored shade-nets (pearl, red, blue and black) with different relative shading (40% and 50%), obtained from Polysack Plastics Industries (Nir-Yitzhak, Israel) with exposure to full sunlight used as control. The average air temperature (at 15^h middle of July) between different color shade net was 1 °C(pearl and red) and 3.0 °C (black) less in comparison with air temperature in open field (control). Advantages of color-shade net is reflected in temperature control: it improves productivity by moderating extremes of temperatures. Air movement is restricted, thus reducing wind damage to the crop and evaporation of soil moisture. Air beneath the shade cloth stays humid for the benefit of plant. Wind speed inside the screenhouse was reduced by more than 50%.Under high solar radiation conditions (in South Serbia in July and August) value of Photosynthetic photon flux density (PPFD) is about 1600* $\mu mol \cdot m^{-2} \cdot s^{-1}$*, so unshaded plants were exposed to high heat stress throughout the growing season. Value for PPFD varied between over1700* $\mu mol \cdot m^{-2} \cdot s^{-1}$ *on sunny days and 700 to 920* $\mu mol \cdot m^{-2} \cdot s^{-1}$ *when cloudy.*

Key words: *color-nets, shading, microclimate condition, solar radiation, yield*

1. INTRODUCTION

During the last decades, due to increased air temperature and intensity of solar radiation caused by climate changes known as '*global warming'* an increasing area of crops is being grown under shading materials of various types. ColorNets represent a new agro-technological concept, which aims at combining the physical protection, together with differential filtration of the solar radiation [23]. They are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing. It is either applied by itself over net-house constructions, or combined with greenhouse technologies. The ColorNet approach was evaluated in numerous ornamentals [12], vegetables [7, 6], fruit trees and vineyards [17]. Netting is frequently used to protect agricultural crops from excessive solar radiation (shade-nets), improving the thermal climate [9], sheltering from wind and hail and exclusion of bird and insect-transmitted virus diseases [25]. The shading of crops results in a number of changes on both local microclimate and crop activity. These changes on local microclimate modify CO_2 assimilation and consequently crop growth and development [9]. Under shading nets the air temperature was lower than that of the ambient air, depending on the shading intensity [11, 22]. In the last years a wide dissemination of agricultural plastic nets was recorded because they have benefical effects on the crops [15].Pepper grown in an arid region under red and yellow shade nets, had a significant higher yield compared with black nets of the same shading factors [7]. The total area of protected vegetable cultivation in different types of greenhouse in Serbia reached 2-3.000 ha and the main vegetables are peppers, tomatoes, and cucumbers [5].

2. MATERIAL AND METHOD

The pepper (*Capsicum annum* 'Cameleon') was grown during 2009-2011 in a greenhouse tunnel (2.2 m high), covered with a polyethylene film (0.15 mm thick; Ginegar Plastic Products-Ltd.) and in the open field. The shading nets were combined with greenhouse technologies or mounted on a structure about 2.2 m in height over the plants in a screen house. The experiments were performed in an experimental plot located in the village of Moravac near Aleksinac, (Longitude: 21^{o}42' E, Latitude: 43^{o}87 30' N, altitude 159 m) in the central area of south Serbia.

In order to test the effect of shading nets (color and shading intensity), four different shading nets were used: the photo-selective nets including 'colored ColorNets' (red, blue and black) as well as 'neutral-ColorNets' (pearl) with shading intensity of 40% and 50% relative shading. The colored shade nets were obtained from Polysack Plastics Industries (Nir-Yitzhak, Israel) that operates under the trademark ChromatiNet. These nets are unique in that sense that they both spectrally modify as well as scatter the transmitted light. The photo-selective net products are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing.

The plants were grown following the technique usually implemented by the local producers. Seedlings were transplanted on May 5th (plant density was 5.6 m^{-2}), the shading nets were subsequently installed above the crop on June 10th (35 days after transplanting) and the measurements were carried out until September 5th. All plants were irrigated using drip irrigation. A completely randomized block design was used, with four blocks assigned to each of four treatments (black, pearl, blue and red net) plus control. Each treatment and block consisted of four rows of 20 plants.

Monthly and daily meteorological data from May 2009 to September 2011 were used from the meteorological stations in Niš(Fig.1) and Aleksinac(Fig.2). For production conditions in tunels laboratory equipment from the Department for Agricultural

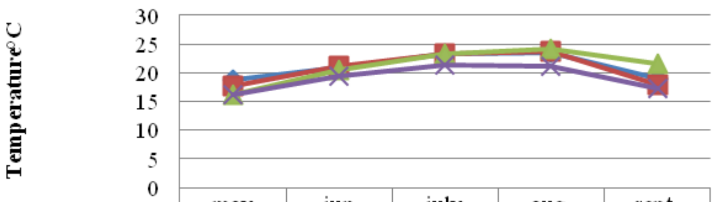
Engineering, Faculty of Agriculture Belgrade was used. It consists of data loggers for measuring temperature and relative humidity. Air temperature was measured in the greenhouse and outside of greenhouse. For that purposes WatchDog Data Logger Model 110 Temp 8K, was used. Air relative humidity was also measured outside and in the greenhouses. Watch Dog Data Logger Model 150.

The photosynthetically active radiation (PAR) was compared to the open field microclimate and production. The effect of nets on the interception of light was measured annually as a percentage of total PAR above canopy, using a Ceptometer model Sun Scan SS1-UM-1.05 (Delta-T Devices Ltd Cambridge, UK) with a 64-sensor photodiode linearly sorted in a 100 cm length sword. Readings are in units of PAR quantum flux (μmol $m^{-2}\cdot s^{-1}$). All measurements were conducted on clear days at noontime. Measurements of global radiation were made every second day, three times during the day. The Solarimeter- SL 100 is an easy-to-use portable autonomous Solarimeter that measures solar radiation range from 1 $W\cdot m^{-2}$ to 1300 $W\cdot m^{-2}$. All spectral data were expressed as radiation intensity flux distribution in $W\cdot m^{-2}nm^{-1}$.

The data were analyzed by analysis of variance (ANOVA) followed by Tukey's HSD test, using the Statistica 6.1 software (Statsoft, Tulsa, OK, USA). All analyses were performed at a 95 % level of confidence ($p<0.05$).

3. RESULTS AND DISCUSSION

Due to increasing uniform temperatures of air (Fig.1 and 2) and the intensity of solar radiation, caused by global warming, an increase in crop area under shading materials has been observed.



	may	jun	july	aug.	sept.
2009	18,7	20,9	23,3	23,5	19
2010	17,7	21,2	23,4	23,8	18
2011	16,3	20,6	23,2	24,1	21,5
1961-1990	16,1	19,5	21,3	21,1	17,2

Fig. 1 The mean daily temperatures in the vegetation period during 2009-2011
(data from the meteorological station in Niš)

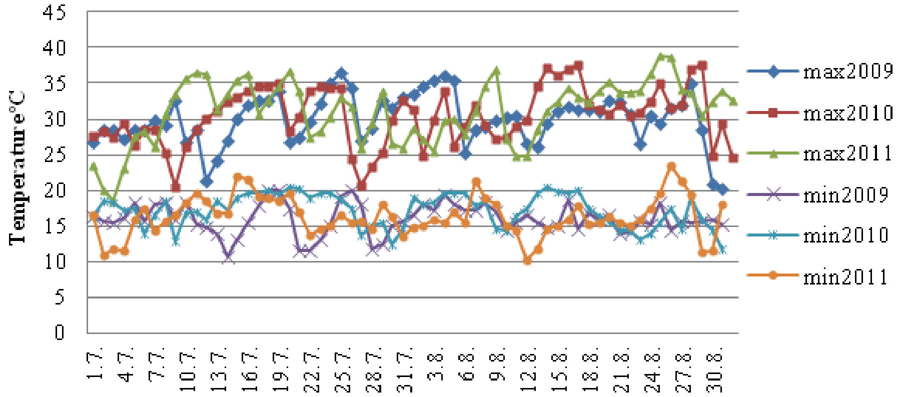


Fig. 2 Daily maximum and minimum temperatures over the period July 1st –August 30th for the 2009, 2010 and 2011. (data from meteorological station in Aleksinac)

Shade nets decrease maximum daily temperatures at extreme conditions. Shade nets are often deployed over crops to reduce heat stress [3, 19].

Table 1 Influence of shade net to the climatic parameters (air temperature, air humidity,wind speed, soil temperature) of sunny day in July (16.07.2009.)

Color nets	Climatic characteristics	Time of the day				
		7^{30}	12	14^{30}	18^{30}	21
Pearl	The air temperature°C	23.4	34.2	36.5	32.3	23.3
	Air humidity %	54	36	30	45	70
	Wind speed m/s	0	1	1.2	0	0
	Soil temperature (5cm) °C	22.0	23.5	24.0	24.5	25.0
Red	The air temperature °C	23.8	33.5	36.5	31.9	23.4
	Air humidity %	52	35	29	35	70
	Wind speed m/s	0	1.1	1.2s	0	0
	Soil temperature (5cm) °C	21.0	23.0	24.0	24.5	24.5
Blue	The air temperature °C	23.4	33.4	36.4	31.7	23.0
	Air humidity %	55	35	29	35	71
	Wind speed m/s	0s	1.1	1s	0s	0
	Soil temperature (5cm) °C	20.5	22.5	23.5	24.0	24.5
Black	The air temperature °C	23.1	33.4	36.2	30.9	23.0
	Air humidity %	55	36	30	39	70
	Wind speed m/s	0	1	1	0	0
	Soil temperature (5cm) °C	20.0	21,5	22.0	22.5	23.0
Open field-control	The air temperature°C	25.4	32.9	37.9	31.5	22.8
	Air humidity %	51	33	27	40	67
	Wind speed m/s	1	4.9	6.5	4.1	0
	Soil temperature (5cm) °C	23.0	24.5	26.0	26.5	26.5

Our studies show that in July and August, at high insolation and reduced air circulation ($13\text{-}15^h$), the temperature in shade nets is 1 °C lower (pearl and red) up to 3 °C (black) in comparison to the open field (tab.1). Shading technology on a number of locations in Israel, confirmed a general decrease of maximum daily temperature (T max) for 1-5 ºC, followed by an increase of maximum daily relative air humidity for about 3-10%, under shade nets 30% PAR [20], and similarly [4], state that maximum daily temperature under nets is up to 3 ºC lower and that bigger differences were recorded during bright and sunny days.

At a lower insolation or when it is cloudy, in July at 15 ^{h}, with an increased air circulation, differences between nets and control are smaller, with a tendency of the open field temperature to be lower for 0.5-1.5°C (tab.1) in comparison to red and pearl shade nets 40 and 50% PAR. Nets intercept air and decrease circulation, and therefore temperature beneath them is higher. Minimum daily temperatures in control are the same or lower for 0.1-1 °C in comparison to shade nets because of the greenhouse effect and lower radiation at that time of a day. [4] had similar results. Minimal or no effect of the low shading nets on the night air temperatures within the canopies during the summer found was reported[21].

In tunnels integrated with nets, the maximum daily air temperature is lower in comparison to a greenhouse without nets for 2-7 °C, and this difference is bigger with the increase of the shade index percentage and a darker color of nets (blue, black).

The advantage of using shade nets is seen in the control of the air humidity and circulation, and soil moisture, which improves the productivity of plants. The air movement is limited, and therefore the strenght of the wind and ground air evaporation are decreased; the concetration of gases is changed which affects basic physiological processes: photosynthesis, breathing, transpiration. The speed of the wind within a shade net is decreased for up to 50%. At the wind speed of 12-16.7 m/s in the open field, the values on shade nets are 6.5-9.7 m/s depending on the density of shade of photo-selective nets. With the increase of net density, the speed of air circulation decreases. The effects on air movement depend on the porosity and physical location of the netting in relation to the plants and can be affected by time of day, season, and other factors [24]. The air under nets remains humid, which is benifical for plants. The air humidity at the period of highest insolation is for 8-10% bigger in plastic houses covered with nets in comparison to plastic houses without nets (control). In shade nets, differences in the air humidity percentage are smaller, but in the black shade net and according to the weather conditions, it is up to 5% higher in comparison to the open field. Relative humidity values are often higher than outside as a result of water vapor being transpired by the crop and reduced mixing with drier air outside the netted area [3], even when temperatures under the netting are higher than outside [24]. Due to decreased evaporation, the temperature of the soil in tunnels integrated with nets, at 5cm depth, is for 2-4 °C lower than in tunnels without nets (26-28 °C), and in shade nets it is 2-3 °C lower in comparison to the open field (24-27 °C).

The climate in the south-east Serbia is continental, which means that summers are hot and dry. The radiation in July and August is high, it can reach over 1700 µmol $m^{-2}\cdot s^{-1}$ and it is most frequently followed by temperatures above 35 °C. It is very similar to the climate of south Europe in the dry area: 1500-2000 µmol $m^{-2}\cdot s^{-1}$, where even when it is overcast Photosynthetic photon flux density-PPFD is 800-900 µmol $m^{-2}\cdot s^{-1}$ [4]. Such climate conditions cause stress on agricultural plants and lead to numerous physiological damages (sun scald on fruit, cracking of fruit – skin, presence of scars on flowers with fruit deformation followed by developing disease). The application of shading (26-47%) in growing peppers leads to a decrease of burns on fruit from 36% in the open filed to only 3-4% [13]. At the end of August 2011, a heat wave of temperatures 37-40 °C high, caused sun scald on pepper fruit in the phase of their technological maturity in the open field, thus lowering the market yield for 12%. Under shades, in all treatments, none of these changes appeared. Therefore, this justifies the use of photo-selective nets. Sun scald usually appear when the air temperature is high, and the number of sunny hours lasts longer during the period of ripening [10].

Table 2 Solar radiation and Photosynthetically Active Radiation (PAR) at noon -July

	Photosynthetically Active Radiation (PAR) µmol $m^{-2}\cdot s^{-1}$ on a sunny day				Photosynthetically Active Radiation (PAR) µmol $m^{-2}\cdot s^{-1}$ on a cloudy day			
	Tunnel +color nets		Only color nets		Tunnel + color nets		Only color nets	
Shade	***40%***	***50%***	***40%***	***50%***	***40%***	***50%***	***40%***	***50%***
Red	832.3	708.4	962.0	798.8	333.4	268.2	521.0	412.6
Black	703.1	647.6	771.8	702.6	202.6	171.3	420.8	243.8
Pearl	813.9	691.3	993.6	805.1	370.4	296.6	539.9	378.5
Blue	756.6	662.8	889.7	768.7	292.0	242.8	464.9	314.9
Control	Tunnel 1199.5		Open field 1661.3		Tunnel 692.2		Open field 920.5	

PPFD of a day in July (13-14^h) had a value 1661 µmol $m^{-2}\cdot s^{-1}$ (tab.2). By shading with shade nets, PPFD was lowered to 962 µmol $m^{-2}\cdot s^{-1}$ in the red one, and up to 771 µmol $m^{-2}\cdot s^{-1}$ in the black shade net. The radiation is even lower in the shade nets of shade index 50% PAR (tab.2). The sun rays are intercepted in the tunnels not only by nets but also by a foil which is 150µ thick. PPFD is highest in the tunnel with a red net of the shade index 40% PAR – 832.3 µmol $m^{-2}\cdot s^{-1}$, and the lowest in the tunnel with a black net of the shade index 50% PAR -702.6. Similarly, [8] state that PPFD 1519 µmol $m^{-2}\cdot s^{-1}$ at full insolation, is lowered to 931 µmol $m^{-2}\cdot s^{-1}$ when shaded 40% PAR, that is below 550 µmol $m^{-2}\cdot s^{-1}$ in shade of 60% PAR. As the shade intensity grows, radiation decreases.

In July around 13^h, sun radiation in the tunnel without nets is 761 W/m², which is for 16.4% less in comparison to the open field (910 W/m²). Literature [5] states that the highest radiation in the open field is 950 W/m² which is very similar to Mediterranean regions such as Italy and Greece (1000 W/m²).

Table 3 Reduction (%) of solar radiation (W m^{-2}) of the control at noon in July with different color shade nets

	T+ color-nets		Only color nets		T+ color-nets		Only color nets	
	40%	50%	40%	50%	40%	50%	40%	50%
	Percent loss of radiation (W/m²)compared to the control on a sunny day				Percent loss of radiation (W/m²)compared to the control on a cloudy day			
Red	22.9	27.3	26.4	32.5	31.7	39.4	31.4	36.1
Black	52.4	52.8	50.9	55.9	55.3	62.3	51.0	53.0
Pearl	25.1	30.3	27.3	33.9	42.9	50.0	38.6	48.4
Blue	32.9	38.5	35.8	43.9	45.8	54.7	35.5	43.3
Control	T^+ 761		OF^{++} 910		T^+ 170		OF^{++} 194	

Control: T^+-Tunnel; OF^{++}- open field (exposure to full sunlight).

In the black shade nets 40 and 50%, the radiation is decreased for 50.9% (446 W/m²), that is for 55.9% (401 W/m²) in comparison to the open field. The least intensity of the radiation was also recorded in the tunnels covered with a black net 52.4% (362 W/m²) and 52.8% (359 W/m²) in comparison to the tunnel without nets. A much less difference in the incoming radiation was between the control tunnel -761 W/m² and the tunnel with the net of the least shade intensity 40% PAR red color- only 175 W/m², that is 22.9%

(tab. 3). The results show that the decrease of the radiation is in relation to the shade intensity and a darker color of nets. According to laboratory tests, relationship among the porosity of the net and its transmittance in the solar range, but also many other parameters compete to give diffusion effects of the incident radiation and, consequently, different transmittance and shading effects [15].

However, our studies show that shading crops when it is cloudy can have a harmful effect on the yield. Namely, when radiation is 194 W/m² in the open field, values in shade nets are significantly lower: pearl-119 W/m², red 133 W/m² ,blue 125 W/m² and black 95 W/m². In the tunnels the radiation values ranged from 76 W/m² (black net) to 116 W/m² (red net). In a ten-day cloudy system at the end of June 2010, falling-off blossoms and pepper fruit buds (on the branches of the second and third category was recorded), especially in the tunnels with black and blue nets (data are not presented). Abscission of pepper flowers is enhanced under conditions of low light and high temperature. The results suggest that the flower capacity to accumulate sugars and starch during the day is an important factor in determining flower retention and fruit [1]. The plastic house structure reduces light intensity, thus further shading can have a negative effect. In plastic houses in conditions existing in Brasil with shading 52% PAR, yield is decreased for 20% [14]. Shading has a harmful effect if it is applied when it is cloudy. In England [2] indicate that shading intenisty of 23%, can lead to a decrease of yield for 20%.

Photo-selective nets in colors of different shade index provide specific microclimate conditions, as we stated above, thus having a different effect on the morphology of plants (their height, branching, lenght of side branches), on blooming, fruiting, lenght of vegetation period, market yield. By decreasing the spectrum of blue, green and yellow light, the red shade net increases the red and infrared part of the light spectrum. As a result, pepper plants gain height, branching is not emphasized, but stems are longer and thicker, and leaves are bigger in comparison to other treatments. Fruits are bigger and of high quality, which is similar to statements of this technology designers. These differences in morphological characteristics are not clearly seen in the tunnels. However, blooming and bud forming are excellent in red and pearl nets 40% PAR.

Table 4 The effect of photoselective nets on the yield components in the tunnels integrated with photoselective nets of different color 40% and 50% PAR

ColorNet	Tunnel + net 40% PAR			Tunnel + net 50% PAR		
	Number fruits/plants	Mean fruit weight (g)	Total yield t/ha	Number fruits/plants	Mean fruit wt.(g)	Total yield t/ha
Red	10.8	100.0	60.0	10.3	103.6	59.6
Black	7.9	102.1	44.7	6.8	103.8	39.2
Pearl	11.9	98.8	65.5	11.5	98.3	62.6
Blue	8.8	99.5	48.8	7.9	100.1	44.2
Control	9.1	87.0	44.2	9.1	87.0	44.2
Lsd 0.05	1.134	5.247	6.589	1.047	6.188	5.532
Lsd 0.01	1.651	7.635	9.587	1.523	9.044	8.050

The red net consistently out-performed the pearl [18] and yellow nets. Positive effects of the red net on pepper productivity were also obtained by the group of Fernández-Rodriguez for plastic tunnel cultivation in Almeria, Spain [21]. Growing under screenhouses for the entire season led to better developed plants, bigger fruits and a higher total yield [13]. A higher yield is a result of forming a larger number of fruits per plant, and not of the size of the fruits [16].

Table 5 The effect of photoselective nets on the yield components in different color shade nets 40% and 50% PAR

ColorNet	40% PAR			50% PAR		
	Number fruits /plants	Mean fruit weight (g)	Total yield t/ha	Number fruits/plants	Mean fruit weight (g)	Total yield t/ha
Red	8.1	100.6	45.3	7.7	99.9	42.8
Black	6.9	89.2	34.9	6.2	89.0	31.0
Pearl	8.5	99.2	47.3	7.9	98.5	43.2
Blue	6.9	94.4	36.6	6.0	90.2	30.1
Control	7.5	85.9	35.9	7.5	85.9	35.9
Lsd 0.05	0.948	7.484	4.011	0.972	6.776	4.425
Lsd 0.01	1.381	10.890	5.836	1.416	9.860	6.439

Our studies show that pepper yield and quality are better especially when pearl and red nets are used. Fruits are equalized, big, without sun scalds and defects, and they have a thicker pericarp. The largest number of fruits per plant is in the red (8.1) and pearl (8.5) photoselective net with shade index 40% PAR, while in the black net 50% PAR there is 6.2-89.2g fruit per plant (tab.5). In the pearl net tunnel there is the largest number of fruits (11.9) and the least is in the tunnel covered with a black net (6.8) of shade index 50% PAR. The control fruit mass (87.0g) is considerably smaller in comparison to color nets treatments (98.3-103.6 g) (Tab. 4). [13] indicate that the lowest number of fruits per plant was obtained under 47% shading at 5 plants m^{-2} density in comparison with 26% shading at 6.7 plants $m-^{2}$ density.

CONCLUSIONS

The photo-selective, light-dispersive shade nets provide a new, multi-benefit tool for pepper production.Using photo-selective net own or in combination with other covering materials, significantly change the microclimate characteristics greenhouses, creating optimal conditions for the performance of the most important physiological processes. The benefit of using a nets of multiple, means better tolerance of plants under stress conditions, the reduced presence of diseases and pests, stable quality agro-economic characteristics of the total fruit themselves, through increased marketing returns. Changing the light intensity and radiation spectrum has a large impact on the total production system The research confirmed the possibility of using the red and white photoselective nets(shade 40% PAR) in order to improve productivity and fruit quality of pepper over the use of traditional black shading networks.

However, further research should provide a better understanding of the physiological mechanisms produced using this technology, and to expand the research to other crops and other environmental conditions.

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INFLUENCE OF FERTILIZER PHYSICAL PROPERTIES ON ITS DISTRIBUTION UNIFORMITY

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Abstract *Modern agriculture is strongly dependent on adequate technological solutions, new technologies and their appropriate application in the use of fertilizers, insecticides, pesticides and soil analysis. Proper choice and efficient utilization of various technological-technical application systems still has a significant importance concerning ecology, energy and economy in agriculture. Production of sufficient quantities of food for the existing population and for future generations is one of the most important tasks of the society. Therefore, the development of agricultural production, its sustainability and continuous improvement is crucial for humanity. The aim of this study was to show how much is important the application of fertilizers in the crop production. In particular, the paper studies the impact of the physical properties of mineral fertilizers on the quality of the application, of course interact with certain technological and technical systems implementation.*

Balanced application of different fertilizers varies, depending on the applied fertilizer and technical systems for the specified application.

Key words: *fertilizer, physical properties, mechanical properties, fertilizer disk spreaders, distribution uniformity.*

1. INTRODUCTION

The number of people on the planet is increasing daily. In 1980 about 4.4 billion people lived in the World, while in the 2000 there were already 6.2 billion. It is estimated that the number 2025 will reach 8.3 billion, which means that for 45 years the human population has virtually doubled itself [2]. Natural soil fertility and genetic potential of crop plants have the ability to increase food production. It is a well known fact that plants through assimilation with the help of mineral nutrients and solar energy can produce organic matter, which is the basis of human and animal nutrition. It is necessary to take care of soil fertility constantly [8]. In the first place care must be taken with fertilizers and then watering. Fertilizing is the agro-technical measure that can influences crop production 60-70%, while the percentage of all other factors is 30-40% [4, 9]. Attempt to restore the production of old crop varieties, based on natural soil fertility, in order to the so-called “health food” does not fit in the tendency of human population growth. Organic production for selected elite while a third of the world's population is starving certainly is neither acceptable nor fair solution.

The goal of scientific research in the area of agriculture is continuous improvement of scientific methods of production and production control, with the use of modern analytical methods. It is to be expected that these together should be able to provide enough quality food for all the people. At present, it is generally accepted worldwide that the use of mineral fertilizers is necessary in intensive crop production to provide high yields. Therefore, great attention should be taken when doing the research about this complex and energy demanding operation. A very important part in whole fertilizer production and application system is application in the field. If it is carried without necessary attention, it could have a negative effect on the whole crop production system in energy, economy and ecology sense. Having a consistent and accurate fertilizer spread pattern is a key requirement for the spreaders industry. It is necessary to meet current farming requirements and expectations. A large number of factors have been identified to have an effect on the distribution of fertiliser particles from a spreader. These factors can be divided into three main categories, in relation to the environment, where the spreading is taking place, the machine and the fertiliser’s characteristics [6].

This paper concentrates on the mechanical properties of the fertiliser material, with particular reference to the particle size distribution within the material and its effect on distribution uniformity along the working width. In the process of application special attention must be paid on the physical and chemical properties of mineral fertilizers and their effect on the uniformity of the distribution in the field [3]. This paper presents results of experimental testing of three types of centrifugal fertilizer spreaders working with three different granular fertilizer types. These types of spreaders enable equal distribution of fertilizers in the transverse and longitudinal direction, with full and partially empty bunker, different speed and a different application rates. Centrifugal type of spreader is adapted to a variety of fertilizers having the possibility of changing the position of disposal angle and position of the blades [5, 7]. The research was carried in order to analyze the influence of fertilizer mechanical properties on the uniformity distribution and overall application efficiency.

Recent studies have shown that special attention must be given to the fertilizer application efficiency [10]. Characteristics of fertilizers affect the quality of the operation dissipation, and this affect continues thought the complete production cycle [4]. Consequently a significant proportion of all these factors take part in the energy efficiency of plant production and in preservation of the economic and ecological production sustainability [2].

2. MATERIAL AND METHOD

In this paper the results of three different centrifugal fertilizer spreaders testing are presented and analyzed. The tested spreaders were Vicon Rota Flow, RCW Agromehanika Kranj and Amazone ZG-B 8200. Experiments were carried out in production conditions of the Agricultural Company Belgrade. Vicon and RCW spreaders were tested in conditions of urea application in commercial maize seedbed preparation in the 2009/10 and in sunflower in the 2010/11 season. Spreaders were also tested in conditions of KAN application in seedbed preparation for soybean and sugar beet in the 2011/12 season. Vicon and Amazone spreaders were tested in the MAP application and

Vicon and RCW spreader in the NPK application in conditions of winter wheat and winter barley in the seasons 2011/2012 and 2010/2011.

Used fertilizers were produced in Serbia (KAN, MAP and NPK) and in Romania (Urea). Vicon Rota Flow spreader is carried fertilizer spreader with two discs and six blades each with the hopper capacity of 2000 l and working width 10 to 36 m [11]. RCW is drawn two discs fertilizer spreader with the hopper capacity of 2000-3500 kg and 10 - 20 m working width [12]. AMAZONE two discs fertilizer spreader has high hopper capacity and robust trolley for speeds up to 50 km/h. The standard equipment includes the automatic self-regulation straps at the bottom for the even distribution of fertilizer on the discs. Hopper capacity is 5500/8200 l and working width in the range between 10 m and 36 m [13].

Uniformity of fertilizer distribution was analyzed from the samples gathered along the spreader working width. For sample collection, cylinder plastic trays were placed along the spreader width. The tray diameter was 10.5 cm [1]. Sample mass was determined by means of precise weighing machine Kern 572/573/KB/DS/FKB/FCB Version 5.8, 04/ 2010 with the precision level of 0.01 g. Particle size distribution within the sample was determined with the Vicon Greenland Art.nr. meter 797770150, with the hole diameters of smaller than 2 mm, larger than 2 mm and larger than 3.3 mm.

3. RESULTS AND DISCUSSION

First tested fertilizer was urea in conditions of seedbed preparation for maize and sunflower. Seedbed preparation for maze was carried in April, 2010. The following weather conditions were determined: temperature 23 ^{0}C, relative humidity 40.9% and west wind maximum speed 1.5 m/s. The average speed of both VICON and RCW spreaders was 12.5 km/h and given application rate 250 kg/ha. Working width of the Vicon spreader was 16 m, while of RCW 12 m. Rudimentary parameters that characterize fertilizer distribution are given in Table 1.

Table 1 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass (the arithmetic mean), g	0.144	0.175	0.150	0.192	0.108	0.176
Standard deviation, g	0.05 8	0.079	0.043	0.073	0.048	0.070
Coefficient of variation, %	40.28	45.14	28.67	38.02	44.44	39.77
Average application rate, kg/ha	166.47	202.31	173.41	221.97	124.86	203.47

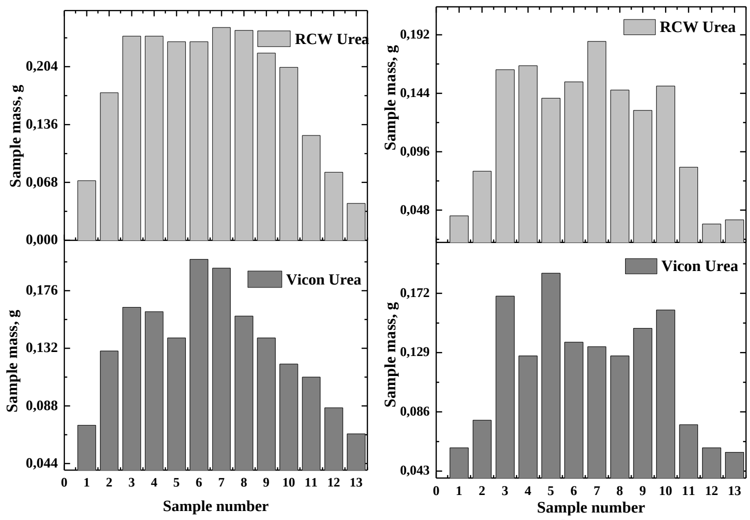
On the basis of results (Tab. 1) it can be seen that the coefficient of variation is to high in case of both spreaders showing that uniformity distribution along the working width is not adequate. Regarding the application rate it can be seen that the RCW spreader shows better results. The reason for this can be searched in the fact that the VICON spreader is mounted while RCW spreader is trailed, having the better stability on the soil.

Seedbed preparation for sunflower was carried in April 2011. The following weather conditions were recorded: the air temperature was 23.8 ^{0}C, air humidity 26.9% and southeast wind velocity of 1 m/s. The average working speed of both spreaders varied from 10.5 to 11 km/h and given application rate 150 kg/ha. Working width of the Vicon was set to 18 m, while in the case of the RCW was 15 m. Data about the uniformity distribution are given in Table 2.

Table 2 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass, (the arithmetic mean)g	0.115	0.117	0.125	0.118	0.113	0.125
Standard deviation, g	0.046	0.052	0.051	0.054	0.043	0.058
Coefficient of variation coefficient, %	40.00	44.44	40.80	45.58	38.05	46.64
Average application rate, kg/ha	132.95	135.26	144.51	136.42	130.64	144.51

It can be concluded that, in this case, the coefficient of variation also has a high value even higher if compared with the previous case. Wind speed change influenced that overall fertilizer distribution uniformity. Uniformity of fertilizer distribution is presented in Figure 1. It can be seen that the RCW spreader has a better distribution and needs a smaller overlapping.



(a) (b)

Fig. 1 UREA distribution uniformity in (a) maize and (b) sunflower seedbed preparation

Sugar beet seedbed preparation was carried in March 2012. Applied fertilizer was KAN. Recorded weather conditions were: temperature 13.6 ^{0}C, air humidity 68.7% and north-west speed of 2 m/s. The average working speed of both spreaders was 10 km/h and standard application rate 250 kg/ha. Working width of the Vicon spreader was 16 m while of RCW it was 12 m. Data about the uniformity distribution are given in Table 3.

Table 3 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass, (the arithmetic mean)g	0.154	0.134	0.153	0.152	0.155	0.159
Standard deviation, g	0.075	0.071	0.069	0.078	0.073	0.085
Coefficient of variation, %	48.70	52.99	45.09	51.36	47.10	53.46
Average application rate, kg/ha	178.03	154.91	176.88	175.72	179.19	183.82

High values of Coefficients of variation indicate the unfavourable working conditions in sense of wind speed and poorly seedbed preparation that left behind a large portion of larger soil fragments.

Soybean seedbed preparation was carried in March 2012. Applied fertilizer was KAN. Recorded weather conditions were: air temperature 18.4 ^{0}C, air humidity 72.4% and the northwest wind speed of 1 m/s. Standard application rate was 200 kg/ha. Working width of the Vicon spreader was 18 m and of the RCW 15 m. The average speed of both fertilizers varied from 11.5 to 12 km/h. Data about the uniformity distribution are given in Table 4.

Table 4 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass (the arithmetic mean), g	0.139	0.135	0.138	0.142	0.138	0.147
Standard deviation, g	0.059	0.055	0.059	0.050	0.053	0.046
Coefficient of variation, %	42.45	40.74	42.75	35.21	38.41	31.29
Average application rate, kg/ha	160.69	156.07	159.54	164.16	159.54	169.94

Uniformity of distribution is presented in Figure 2. Again RCW spreader had a better uniformity which has pattern similar to that called “pyramid pattern” (Stewart and Bandel, 2002). This makes it more suitable for the modelling and optimisation. Although this is an acceptable pattern, the effective swath width is only 50% of the theoretical.

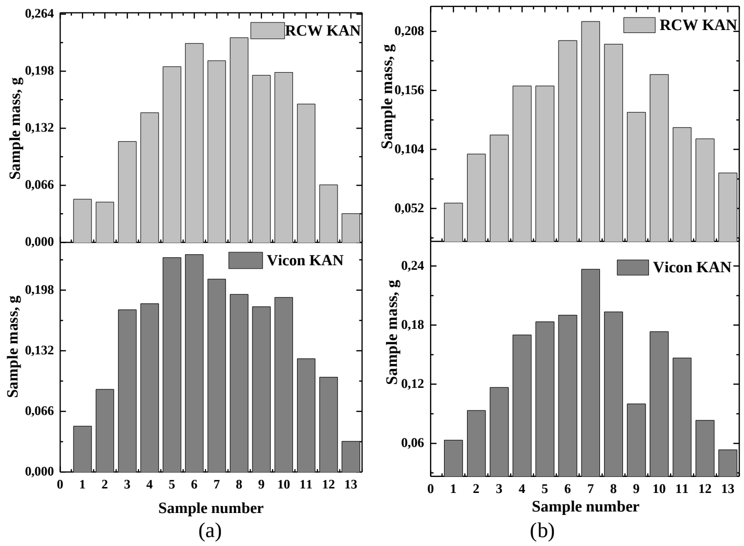


Fig. 2 KAN distribution uniformity in (a) sugar beet and (b) soybean seedbed preparation

Winter wheat seedbed preparation was carried in 2010/2011. Applied fertilizer was NPK 20:20:0. Recorded weather conditions were: air temperature 19 ^{0}C, air humidity 27% and southeast wind speed of 1.5 m/s. Standard application rate was 200 kg/ha. Working width of the Vicon spreader was set to 18 m and for RCW to 15 m. The average working speed of both spreaders was 13 km/h. Data about the uniformity distribution are given in Table 5.

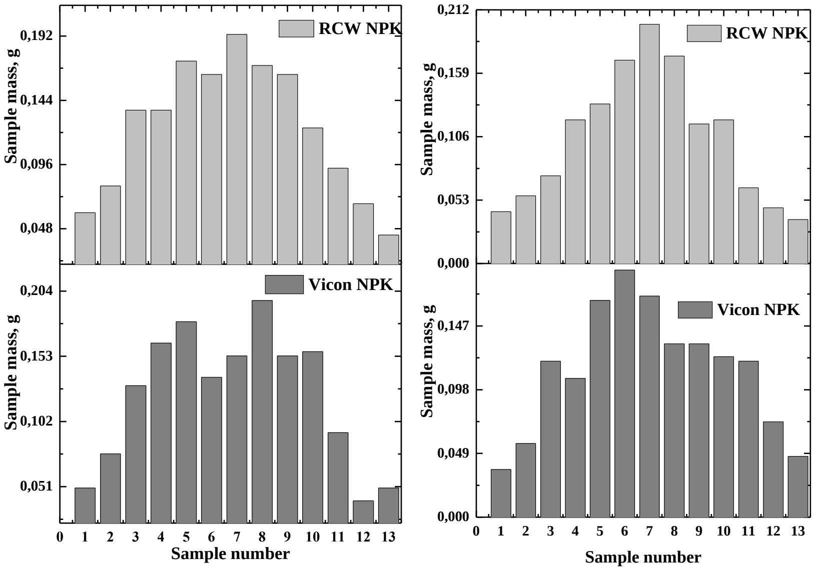
Table 5 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass, (the arithmetic mean),g	0.110	0.127	0.130	0.118	0.122	0.128
Standard deviation, g	0.047	0.053	0.060	0.051	0.053	0.058
Coefficient of variation, %	42.72	41.73	46.15	43.22	43.44	45.31
Average application rate, kg/ha	127.17	146.82	150.29	136.42	141.04	147.98

Winter barley seeding was carried out in October 2010. Applied fertilizer was NPK 20:20:0. Recorded weather conditions were: air temperature 19 ^{0}C, air humidity 27% and southeast wind speed of 1.5 m/s. Standard application rate was 150 kg/ha. The working width of the Vicon was set to 16 m while fro the RCW it was 14 m. Average working speed of the spreaders was 12 km/h. Data about the uniformity distribution are given in Table 6 and presented on Figure 3.

Table 6 Uniformity distribution parameters for the VICON and RCW spreaders

Parameter	I probe		II probe		III probe	
	Vicon	RCW	Vicon	RCW	Vicon	RCW
Average sample mass (the arithmetic mean), g	0.109	0.105	0.122	0.100	0.118	0.108
Standard deviation, g	0.053	0.059	0.059	0.053	0.053	0.051
Coefficient of variation, %	48.62	56.19	48.36	53.00	44.92	47.22
Average application rate, kg/ha	126.0	121.39	141.04	115.61	136.42	124.86



(a) (b)

Fig. 3 NPK distribution uniformity in (a) wheat and (b) barley seedbed preparation

Seedbed preparation for winter wheat was carried in October 2012. Applied fertilizer was MAP. Recorded weather conditions were: air temperature was 22 ^{0}C, air humidity 26% and the northeast wind speed 1 m/s. Standard application rate was set on 90 kg/ha. Average working speed 15 km/h. Amazone spreader working width was 32 m and Vicon 18m. Data about the uniformity distribution are given in Table 7.

Table 7 Uniformity distribution parameters for the VICON and AMAZONE spreaders

Parameter	I probe		II probe		III probe	
	Vicon	Amazone	Vicon	Amazone	Vicon	Amazone
Average sample mass (the arithmetic mean), g	0.050	0.066	0.052	0.064	0.048	0.065
Standard deviation, g	0.022	0.018	0.023	0.020	0.021	0.020
Coefficient of variation,%	44.00	27.27	44.23	31.25	43.75	30.77
Average application rate, kg/ha	57.80	76.30	60.12	73.99	55.49	75.14

Seeding of winter barley was carried out in October 2012th year. MAP fertilizer was applied. The research was performed the same day as the winter wheat already mentioned, and the weather conditions were the same. Standard application rate was up to 70 kg/ha. The width of the Vicon was 16 m, while of Amazon was 30 m. Speed of both units were on average 15 km/h. Data about the uniformity distribution are given in Table 8. Distribution uniformity is presented on Figure 4.

Table 8 Uniformity distribution parameters for the VICON and AMAZONE spreaders

Parameter	I probe		II probe		III probe	
	Vicon	Amazone	Vicon	Amazone	Vicon	Amazone
Average sample mass (the arithmetic mean), g	0.048	0.062	0.052	0.058	0.057	0.062
Standard deviation, g	0.022	0.20	0.021	0.016	0.020	0.018
Coefficient of variation, %	45.83	32.26	40.38	27.59	35.08	29.03
Average application rate, kg/ha	55.49	71.68	60.12	67.05	65.90	71.68

Figure 4 shows a great misbalance in the distribution uniformity. No clear pattern can be seen. For Amazone spreader one of the reasons of poor uniformity is that it was a new machine and that the operator did not have much experience with it.

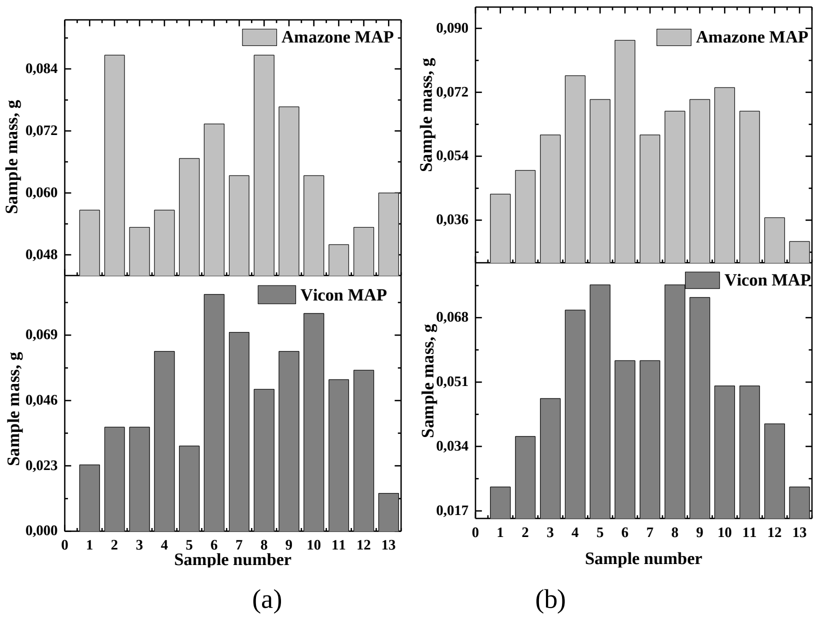


Fig. 4 MAP distribution uniformity in (a) wheat and (b) barley seedbed preparation

In further analysis particle size distribution was carried. Samples for each fertilizer were taken from the storage, spreaders hoppers and from the plot, after the application. The aim of this study was to determine the potential correlation between fertilizer granule size and uniformity of its application. Tables 9 and 10 give the particle size distribution for each fertilizer and for all three sampling locations.

Table 9 Particle size distribution in the fertilizer samples from storage and from the spreader [%]

Particle diameter, mm	Fertilizer from the storage, %				Fertilizer in the spreader, %			
	UREA	NPK	KAN	MAP	UREA	NPK	KAN	MAP
d > 4.75		2.14	13.90	1.79		3.59	19.25	0.22
3.3 < d <= 4.75	1.63	60.67	46.72	12.47	3.13	52.50	42.79	7.67
2 < d <= 3.3	32.94	28.72	21.23	71.41	20.03	33.69	18.10	86.3
d <= 2	65.43	8.47	18.15	14.33	76.84	10.22	19.86	5.81

Table 10 Particle size distribution in the fertilizer samples after application [%]

Particle diameter, mm	Fertilizer after application, %			
	UREA	NPK	KAN	MAP
d > 4.75		1.46	23.81	0.56
3.3 < d <= 4.75	0.45	63.75	55.99	6.26
2 < d <= 3.3	6.87	28.66	13.71	77.2
d <= 2	92.68	6.13	6.49	15.68

The results show that the samples are largely unhomogeneous. There is no pattern to be followed concerning the particle size distribution in the samples and regarding the manipulation process. With MAP and UREA sample, the share of smaller particles is growing after the application. On the other hand in the case of NPK and KAN the share of smaller particles is lower after application. This can be explained with the fact that smaller particles are susceptible to the wind. Higher share of smaller particles of MAP and UREA fertilizers can explain their uniform application along the working width. Uniform application can also be explained with the fact that the soil on the plot was not well prepared with high share of larger soil aggregated.

4. Conclusion

Tests have shown that there are a lot of factors that affect the fertilizer distribution uniformity. While the mode of application is identical in all cases, the characteristics of fertilizer spreader settings and weather conditions contributed to the different quality of distribution in different cases.

Filed testing of the three type of two-disk fertilizer spreaders showed that, even with the same working conception, their distribution patterns were different. Real application rate varied significantly along the working width. Coefficients of variation showed that no good uniformity was achieved. Further analysis of the particle size distribution showed that fertilizer manipulation prior to application (storage, transportation...) causes the creation of larger number of smaller particles that were susceptible to wind conditions during the field testing. Optimization and modeling for calculating the optimal overlapping of the spreader working width, based on the mechanical properties of the fertilizer, local weather conditions during the application and the characteristic of the spreader will be future part of the research.

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Expert paper

WORKING PARAMETERS OF THE TRACTOR-MACHINERY TILLAGE SYSTEMS IN FRUIT PLANTATIONS

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Abstract: *Soil tillage is concerned as necessary if good mechanical and structural properties of soil are needed. Together with the other operations it defines plant growth, yield and products quality. Sustainable and profitable production is achieved with the optimal choice of tillage systems. If intensive fruit production is desired than optimal exploitation and working parameter of the mechanized systems must be defined. This paper presents energy and exploitation analysis of the working parameters of tractor-machinery systems, in tillage. Based on the results obtained it was possible to define advantages and disadvantages of the tested tillage systems. It was concluded that optimal result in tillage were achieved with the chisel plough.*

If fruit production is established in the arid condition than soil tillage must be carried on whole surface. In this way mechanical structure of the soil will enable better water/air regime, easier weed control and better energy, ecology and economy efficiency.

Key words: *tractor-machinery systems, fruit plantations, soil tillage, energy analysis.*

1. INTRODUCTION

Quality and efficient tillage of soil in perennial plantations is a complex and energy-consuming agro technical measure. In the course of vegetation, fruit trees consume large quantities of water in the form of transpiration, which is one of their physiological functions. In areas with the arid climate with no irrigation, the moisture indispensable in the soil, can only be accumulated and the rational used with high quality primary and additional cultivation [23].

Choosing an appropriate tillage method reduces costs and helps environmental protection [2]. The development of technology, particularly information and communication technologies, have significantly improved the agricultural machinery [15]. The transition from conventional to the new technologies in primary production should be achieved gradually, using scientific and professional knowledge [13]. By selecting appropriate technological processes and machines it is possible to achieve greater economic and energy efficiency, in the same time preserving the ecological environment and soil [14, 21].

The results of the specific production conditions indicate the possibility of energy savings and increasing productivity of aggregates in the soil cultivation [17]. Arvidsson et al, [1] have defined the pulling force for three different tillage (cultivation) systems, using ridge plough, subsoiler and disc plough at different conditions of soil moisture. Chen et al, [5] studied compaction poorly drained clay soils, comparing systems of conventional cultivation, sub soiling (undermining) and no cultivation.

Reduced systems of cultivation compared with conventional cultivation with ridge plough, make significant difference in savings of energy, machinery and human labour per unit of cultivated surface [19]. Güclü et al, [8] were using in the experiments two cultivation systems (conventional tillage/cultivation with ridge plough and reduced tillage with subsoiler). The transition from conventional cultivation to reduced cultivation made possible the use of deep loosening / sub soiling in the first year [9]. The introduction of zero cultivation can avoid or reduce degradation of productive soil [3] and [4].

The period of usage and fruitfulness of fruit trees, so as fruit quality, are in major part conditioned by technology of cultivation. Practice in the soil cultivation shows that cultivation engage a large amount of energy. Many studies show that the total energy consumption during the cultivation of fruit crops is from 24.5 to 34.5% of energy [7, 16, 18, 22 and 24].

Mechanical cultivation keeps surface layer of the soil loose, which breaks the capillarity and slows the loss of moisture from the soil. Besides that, destroys the weed vegetation that competes with cultivated plant taking moisture and nutrients in the soil.

Adequate soil cultivation improves the physical and mechanical characteristics, and thus indirectly influences the improvement of other soil properties. The cultivated soil makes favourable conditions for physical, chemical, and microbiological processes. The main task of cultivation is to ensure optimal soil conditions that will enable the rational cultivation of perennial plants.

2. MATERIAL AND METHODS

The field examinations were performed on ODPF "Radmilovac" (Experimental farm of Faculty of Agriculture, University of Belgrade, called "Radmilovac") on "Board IX" in a collection orchard of plum with a row distance of 4 x 3 m. The orchard is located on undulating terrain at an altitude of about 71 m. The geographical position of orchard requires a moderate continental climate and the predominant soil type is cambisol [20].

The experiment included following machine for cultivation: Classic two-furrow plough (double-sided plough) IMT-775, vineyard plough VP 189.7, disc harrow IMT 613.21, IMT cultivator - 642.9 and chisel plough PP-220 (IMT – Agricultural machinery).

Table 1. Technical characteristics of the technical systems

Indicators	Units of measure	Working tool				
		Double-sided plough	VP – plough	Disc harrow/plough	Cultivator	Chisel plough
Number:	-					
-plough bodies		2	7			7
-battery				4		
-working bodies					9	
-hoes			7			
Working width	cm	50	200	210	200	210
Depth of works	cm	23	12-18	15	20	14-45
Mass	kg	235	458	450	200	605
Required power	kW	28	37-52	26	26	55

List of symbols:
H – working depth [cm]
B_z - working width [cm]
Ip – index of plasticity [-]
Po – cultivated area [%]
Eha – specific energy [kWh ha^{-1}]
Fv – drawbar pull [kN]
kt – specific resistance soil [N cm^{-2}]
Pv – power pull [kW]
Q – fuel consumption Hourly [l h^{-1}]
Qha – specific energy [l ha^{-1}]
v – driving speed [km h^{-1}]
Wh – productivity [ha h^{-1}]
η_T –coefficient of utility [-]

During the tests following parameters were recorded:
- Pulling force on the drawbar (measurements with Amsler's dynamograph)
- speed of movement (obtained as the quotient of the passed distance on the 50 m long path and the time which tractor needs to pass the distance),
- time consumption of the fuel (obtained using volume method - gauge),
- specific fuel consumption (calculation method),
- soil bulk density (Kopecky cylinders),
- Consumption of fuel per unit area (obtained as the ratio of hourly consumption and productivity of a given unit/aggregate),
- Soil compaction - soil resistance to pressure (Eijkelkamp Hand Penetrometer, Set A)
- Structural analysis of the soil were done using the Savinov method [12].

Fig. 1. Tools testing

Fig. 2. Measuring the traction/tensile strength of tested aggregates

The resulting of exploitation parameters are used to compute the other quantities, such as: tensile strength and specific resistance.

The moisture level was determined using the Kaczynski method [11], soil samples were taken at depths of 0-10 cm, 10-20 cm, 30-40 cm, and measurements of samples before and after drying in the drying rooms at 105 ^{o}C.

Upper (W_l) and lower (W_p) limit of plasticity was determined by the opening of two profiles: 0 - 20 and 20 - 40 cm.

The value of plasticity index is determined by computing, and shows the difference in the amount of water which makes the upper and lower limits of plasticity [6].

3. RESULTS AND DISCUSSION

3.1. Test results of soil properties

Mechanical cultivation of the soil is determined by the physical properties that have a decisive impact on the quality of cultivation, as well as the energy balance in aggregates functioning. The results of mechanical composition of the soil are shown in Table 2.

Table 2. Mechanical composition of cambisol

Number of repetition	Depth [cm]	% Content					
		Coarse sand >0.2 [mm]	Fine sand 0.2-0.02 [mm]	Powder 0.2 - 0.002 [mm]	Clay < 0.002 [mm]	Total sand >0.2 [mm]	Total clay 0.002 [mm]
1	0-20	-	15.2	37.5	47.3	15.2	84.4
	20-40	-	12.0	34.7	53.3	12.0	88.0
2	0-20	-	21.5	32.8	45.7	21.5	78.5
	20-40	-	21.4	38.1	40.5	21.4	78.6
3	0-20	-	22.4	32.5	45.1	22.4	77.6
	20-40	-	15.2	41.3	43.5	15.2	84.8

The amount of colloidal clay of the fraction of <0.002 mm in the A horizon ranges from 40.5 to 53.3 %, powder from 32.5 to 41.3%, while the fine sand is significantly less than the 12.0 to 22.4 %. Coarse sand, the fraction of > 0.2 mm was not found in any of the profile.

3.2. Soil plasticity and compaction

The values of soil plasticity obtained analytically, are given in Table 3. Plasticity index under conditions examined ranged from 11.17 to 14.87. The plasticity index average value is 12.81. The soil examined in the plum orchard, according to the Atterberg classification, is plastic.

Soil compaction or loading of soil is a soil mass per unit volume, in such a way the soil is considered to be homogeneous which is not.

This characteristic of soil depends on several factors such as the content of water and air within a soil, shape and size of particles, size and shape of the pores between particles, specific gravity of particles, loading of ground, cohesion force acting between the particles, etc.

Penetrometering was carried out at depths of 0-40 cm with a spacing of 10 cm, and measurement results are given in Table 3. Soil moisture ranged from 15.46 % to 21.47 %.

Table 3. Soil compaction

Zone	Depth [cm]			
	0-10	10-20	20-30	30-40
	Compactness [N cm^{-2}]			
1	145.5	185.5	241.5	248.5
2	119.0	205.5	299.0	310.0
3	180.5	323.0	299.0	261.0
1a	267.0	453.5	545.5	559.0
2a	200.0	350.0	394.0	440.0
3a	222.0	375.0	446.0	439.0
1b	289.0	410.0	*	*
2b	260.0	410.0	397.0	377.0
3b	262.0	511.0	549.0	534.0

* beyond the measurement scale of the instrument, higher than 600 N cm $^{-2}$

Measurements carried out by the penetrometer were performed in three zones in the middle of inter-row spacing of the planting (1,2,3), three in the right row (1a, 2a, 3a) and three in the left row (1b, 2b, 3b) uncultivated area. The results show that the soil compaction in the inter-row spacing area which is treated, suffers a change at all depths, especially in the treated area 0-10 cm, 148 N cm^{-2} and 10-20 cm 235.0 N cm^{-2}. Uncultivated area around the rows of plants is significantly more compact, thus has the value of 229.7 and 270.3 N/cm^{-2} (0-10 cm) and 392.8 and 443.7 N cm^{-2} (10-20 cm), and in the zone b_1 at the depths of 20-30 and 30-40 cm the compaction exceeded the value of 600 N cm^{-2}.

3.3. Energy and exploitation parameters of work performed in tillage of plantings

In the fruit-growing practice the primary tillage of the inter-row spacing in the plantings is usually done in the autumn at the depths of 20 cm. Firstly, it is performed in order to accumulate soil moisture, improve its structure and increase the volume as well as to plough plants residues. By contrast, an additional tillage of the inter-row spacing in planting is performed during the growing season at a depth of 10 cm. The main objective of additional tillage is keeping moisture in the soil, grinding and levelling of soil, breaking the crust and destruction of weeds.

The results of the technical systems testing carried in primary tillage are shown in Table 4.

Analysis of Table 4 shows that the primarily tillage by plough was performed at a depth of about 16 cm. Increasing the depth of ploughing directly conditions an increase in fuel consumption per square unit which value ranged about 17 l ha^{-1} of the orchard. In fact, this value represents great amount of energy consumption, which is 95.12 kWh ha^{-1}. Such large energy consumption is a limiting factor of this tillage method and can be justified only by a deeper and more intensive infiltration of the plant residues into the soil.

Table 4. Exploitation parameters of machine-tractor aggregates in the soil tillage

Para-meter	Units of measure	Working tools						
		Primary tillage			Additional tillage			
		Two furrow plough	VP-189 plough	Chisel plough	Disc harrow	Cultiva-tor	VP-189 plough	Chisel plough
H	cm	16.70 15.24 15.97	12.71 11.70 12.20	13.26 15.29 14.27	8.33 6.48 7.34	7.68 4.35 6.01	10.53 11.04 11.18	7.20 5.43 6.31
B_z	cm	75	200	200	240	218	200	212
V	km h^{-1}	4.28 4.33 4.30	4.04 4.29 4.16	6.76 6.18 6.47	5.43 6.86 6.14	5.64 7.64 6.64	4.45 3.93 4.19	6.67 7.92 7.29
Fv	kN	19.21 17.53 18.36	23.83 21.96 22.86	15.88 18.31 17.05	8.73 6.79 7.68	4.66 2.64 3.64	19.74 22.23 20.95	8.62 6.50 7.54
Qha	l ha^{-1}	18.04 16.46 17.26	17.02 15.27 16.16	16.11 14.69 15.41	14.62 11.37 12.88	8.73 6.58 7.68	13.85 14.10 14.75	7.77 5.86 6.81
Wh	Ha h^{-1}	0.83 0.86 0.84	0.85 0.91 0.88	1.23 1.12 1.18	0.74 0.97 0.56	1.20 1.27 1.23	0.84 0.78 0.81	1.28 1.31 1.29
Po	%	56.73 55.40 56.06	65.35 63.75 64.55	76.62 76.20 76.41	67.73 66.19 66,96	68.80 67.54 68.17	65.71 60.90 63.31	66.22 61.06 63.64

Fuel consumption in the primary tillage in the case of V plough was around 15.5 l ha^{-1}, with the productivity of 1.18 ha h^{-1} and the energy consumption of 92.1 kWh ha^{-1}. This type of treatment is very favourable in comparison to the treatment performed by two furrow plough. When comparing the above it should be kept in mind that the tillage in question was performed at a lower depth (average 12 cm) but the profile of the treated surface is more level when treated by V plough. In the additional tillage the V plough consumes 14.23 l ha^{-1}, which is explained by the fact that in the additional tillage performed at a lower depth. Compared to other tools for additional tillage it offers the most uneven soil profile.

From this table it can be seen that in the primary tillage performed by a chisel the highest operating speed is achieved ranging in average from 6.76 km h^{-1} and the lowest using the two furrow plough is 4.28 km h^{-1}. It also reveals the highest average performance achieved by a chisel plough of 1.18 ha h^{-1} and by a two furrow plough is 0.84 ha h^{-1}.

The tillage performed by a disc harrow makes the most level soil profile of the surface but when compared to the chisel and cultivator delivers superior fuel consumption per hectare within the planting.

3.3. Operational quality of tools used for tilling

Rating of work quality indicators was based on measurement of soil fragmentation after machine treatment and measuring soil profile [10]. Table 5 shows the mass portion and percent portion in content of certain fractions after mechanical treatment in inter-row spacing of plantings.

Table 5. Indicators of aggregates performance quality after tillage

Fraction [mm]	Operational tools									
	Two furrow plough		VP - 189 plough		Chisel plough		Disc harrow		Cultivator	
	Mass [g]	Portion [%]	Mass [g]	Portion [%]	Mass [g]	Portion [%]	Mass [g]	Portion [%]	Mass [g]	Portion [%]
< 1	120	3.58	80	2.39	75	2.24	148	4.42	85	2.54
1 – 5	150	4.47	330	9.85	120	3.58	195	5.82	128	3.82
5 – 20	280	8.36	460	13.73	635	18.95	975	29.10	642	19.17
20 – 35	325	9.71	585	17.46	530	15.82	282	8.42	626	18.68
> 35	2475	73.88	1895	56.57	1990	59.41	1750	52.24	1869	55.79

The analysis of Table 5 shows that the fraction of soil below 1 mm is 2.24 % the lowest reported in the case of chisel plough and 4.42 % the highest in disc harrow. Soil fractions of 1-5 mm were lowest in the chisel plough 3.58 %, and the highest 9.85 % in the V plough. Soil fractions of 5 - 20 mm were the lowest 8.36 % in two furrow plough and the highest 29.1 % in disc harrow. Soil fractions of 20 - 35 mm were the lowest 8.42% in disc harrow and the highest 18.68 % in cultivator. Soil fractions larger than 35 mm were the lowest 52.24 % in disc harrow and the highest 73.88 % in two furrow plough. The mass of soil samples used in all tools was the same and amounted 3350 g. Comparing the results obtained through the structural analysis, the most favourable fraction ratio and the soil structure is achieved by chisel plough in the both primary and additional tillage.

4. Conclusion

Modern intensive fruit-growing production is characterized by the large investments in raising and exploitation of plantings including the use of irrigation system. Such method of cultivating plantings enables the procedures for grassing of inter-row spacing areas and excludes the mechanical treatment.

Domestic fruit-growing practice is based, in its greater part, on the extensive production with fewer investments which is why irrigation is not present. This fact points to the need that the soil in plantations should be mechanically treated. In order to achieve more rational use of energy, the reduced treatment which includes the use of classical ploughs should be favoured.

Further studies on tilling soil in perennial plantations in addition the above instruments should also include rotary shovels and vibrating rippers. Research should be conducted in a number of soil types as well as monitoring of production results which would lead to the knowledge about the economic effects of the applied technology.

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Expert paper

AIR VELOCITY AND SPRAYER WORKING SPEED INFLUENCE ON PESTICIDE APPLICATION QUALITY

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Abstract: *The experiment was carried out in a vineyard using a sprayer, in order to determine the effect of air velocity and aggregate movement velocity on the deposition of protective fluid on the leaf surface. Treatment standard during the experiment was 400 l ha^{-1}. Changing the fan capacity by means of a number of rounds of the rotor and blade rotation, air velocities were achieved just in front of the vineyard row: 5.4; 7.8; 10; or 13.2 m s^{-1}. Combining the aforementioned air velocities with sprayer movement velocities of 5.8 and 8.5 km h^{-1}, eight experiment variations were found. Examination results indicate that increase in the sprayer movement velocity from 5.8 and 8.5 km h^{-1} has caused an increase in depositions on the leaf surface up to 25 % on the row side facing the sprayer i.e. about 10% on the opposite side of the row. Based on examination results, we have concluded that the highest deposition on the leaf surface has been achieved at sprayer velocity of 5.8 km h^{-1} and air velocity in front of the row from 8 to 10 m s^{-1}.*

Key words: *sprayer movement velocity, air current velocity, deposited fluid quantity*

1. INTRODUCTION

Pesticide application in vineyards using sprayers is characterized by the issues of reaching adequate air quantity and its current velocity. Air quantity directed towards the target surface depends on the combination of fan output air velocity and sprayer movement velocity.

Modern technical solutions of sprayers ensure air current velocity to be precisely adjusted to blade rotation and through sprayer gearstick transmitter. It can be said that there are still no adequate technical solutions of the sprayer used in vineyard practice [5, 6]. There are numerous sprayers with limited adjustment of a fan air current velocity, due to only two transmission levels within the transmission mechanism of a fan drive [3].

As for the general opinion in vineyard practice, the higher the air current velocity the more efficient the treatment is, especially in full vegetation. However, at a higher air velocity already deposited fluid gets blown away [2]. Such effect is more prominent if air current velocity fails to comply with the treated leaf mass quantity [1].

This issue is interesting concerning the fact that recent examination results within this field have not defined air current velocity values that would be most efficient in vineyards protection. The aim of this paper has been to determine the scope of air velocities for the purpose of defining the optimal sprayer velocity for adequate pesticide application.

2. MATERIAL AND METHODS

Research experiments were carried in a vineyard with interrow and row distance of 2.8 x 1 m with the Guyot growing form. Experiments were carried out in the stadium of full vegetation.

An sprayer with the axial fan, with adjustable capacity from 16 000 to 48 000 $m^3\ h^{-1}$ and output air velocity from 12 to 32 $m\ s^{-1}$ was used to perform the experiment. Distribution system of the sprayer contained 10 Teejet nozzles type TX 8001 and 80015, providing a hollow conical jet. All experiments were carried out with standard application rate of 400 $l\ ha^{-1}$, combining two different sprayer movement velocities (5.8 and 8.5 $km\ h^{-1}$) with four different air movement velocities as entering a vineyard row (5.4; 7.8; 10; and 13.2 $m\ s^{-1}$) measured by an ultrasonic anemometer/windmeter (Gill Wiand Observer 2DI). With each repetition, 90 treated water-sensitive paper sheets were examined. 30 sheets were taken from the row side parallel to the sprayer (A) passage, (Fig. 1) 30 from the opposite side of row (B), and 30 from the second row (C) in order to investigate the deposition quality of the protective fluid.

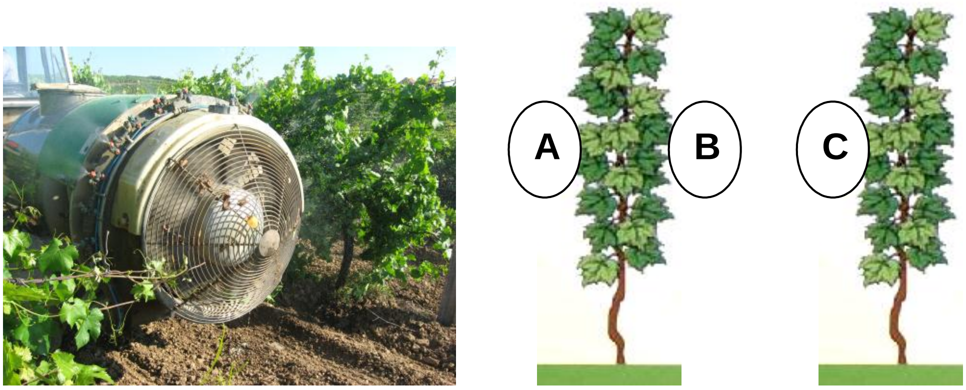

Fig. 1 Tested sprayers in operation and measurement points from which deposited protective liquid was sampled

Quantity of applied liquid was established as a difference between the mass of a clean water-sensitive paper and the mass of a paper immediately upon the treatment and is expressed in μg cm^{-2}. Analytical scales AS 220/C/2 was used to measure clean water-sensitive paper upon the treatment.

3. Results and discussion

Results of the analysis obtained in the experiment lead to the conclusion that the aggregate movement velocity influenced the quantity of a protective fluid deposited on the leaf surface on the row side parallel to the sprayer passage during the treatment.

At the velocity of the sprayer movement of 5.8 km h^{-1}, in comparison with the velocity of 8.5 km h^{-1}, average sediment value on the A side leaves, increased by 26%. Increase in the quantity of the deposited protective fluid on the opposite side of the row (B) and the other side (C) was about 10% when compared to the movement velocity of 8.5 km h^{-1} (Fig. 2).

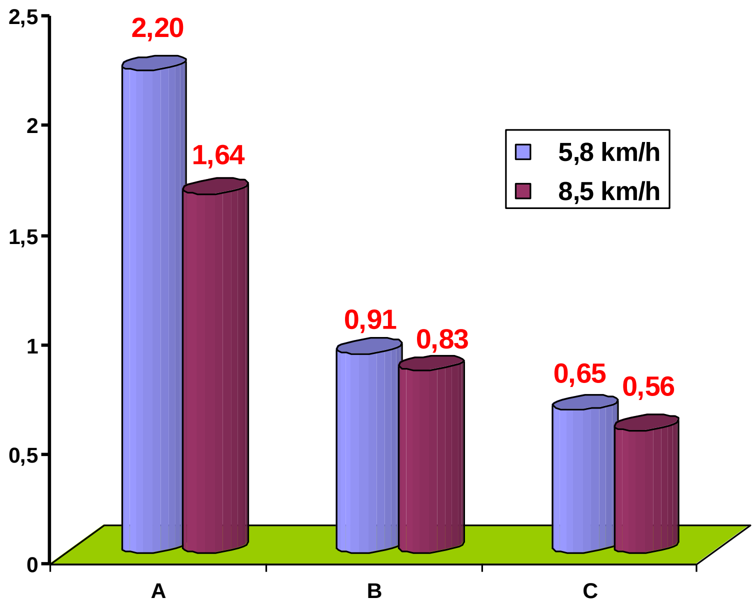

Fig. 2 Influence of the aggregate movement velocity on the deposited fluid quantity

Using different scope of air current velocity produced by a sprayer fan, one could notice different fluctuations in the quantity of deposited drops on the leaves in the row parallel to the sprayer passage (side A and B) with regard to registered values in the second row (side C).

On the leaf surface placed on the side against and on the opposite side of the row, the highest deposition was achieved at the velocity of an air force between 7.8 and 10 m s^{-1}, while in the other row the most complete deposition was realized at the air current velocity of 13.5 m s^{-1}. At the aggregate velocity of 5.8 km h^{-1} the highest t protective fluid quantity on the side (A) was deposited at the air current velocity of about 10 m s^{-1}

i.e. on the side (B) at the velocity of about 7 m s^{-1} and on the side (C) at the velocity of 13.5 m s^{-1} (Fig. 3).

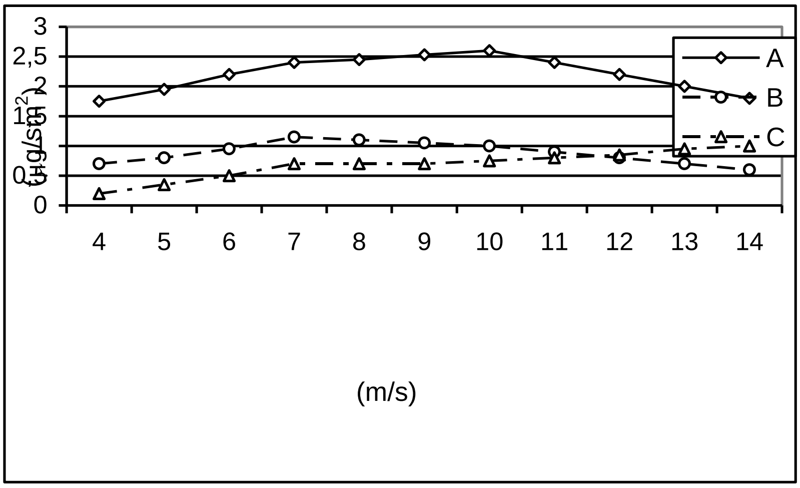

Fig. 3 Deposited quantity of the protective liquid at the aggregate movement velocity of 5.8 km h^{-1}

At the sprayer velocity of 8.5 km h^{-1} the highest protective liquid quantity on the side (A) was deposited at the air current velocity of about 7 m s^{-1} while on the side (B) at the velocity of about 10 m s^{-1} and finally on the side (C) just like in the previous case, at the velocity of 13.5 m s^{-1} (Fig. 4).

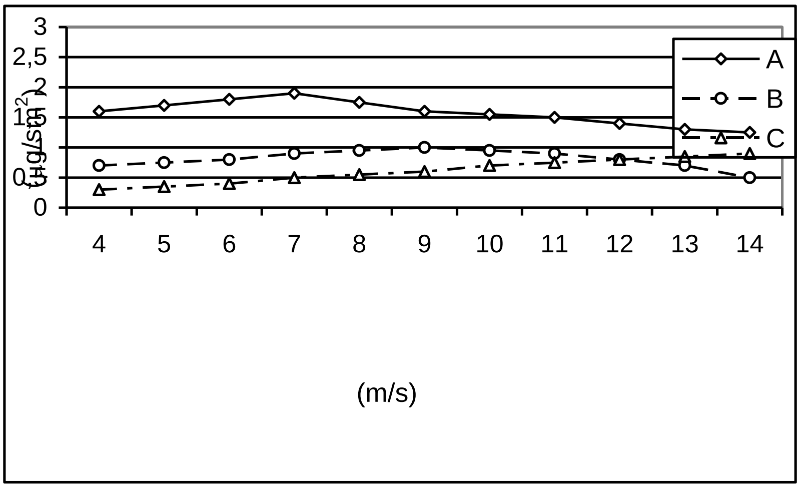

Fig. 4 Deposited quantity of the protective liquid at the aggregate movement velocity of 8.5 km h^{-1}

4. CONCLUSION

As indicated by the experiment results, correctly adjusted velocity and quantity of the air current produced by a sprayer fan can increase quantity of the deposited protective liquid on the target surface. Primarily, increase is attainable at the sprayer movement velocity of about 6 km h^{-1}. Vineyard treatment at the highest vegetative mass, small air current velocities are insufficient for the transmission of all drops to the full plant surface. However, if applied air current velocity is too high, the effect thereof could be adverse, i.e. a part of the drop could be blown away from the target surface. Maximum quantity of drop deposition on the leaf surface is attainable in the full vegetation development stadium, with the above stated sprayer movement velocities and the use of the air current of 8 do 10 m s^{-1}.

Future research will be carried in order to define optimum air current velocity of the sprayer in different phases of vineyard growing stadiums, thus taking into account protective agent quantities applied to the plant surface.

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Case study

EXPLOITATION CHARACTERISTICS OF A DISC ROTARY MOWER DURING ALFALFA CUTTING

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Abstract: *This study presents research result conducted over rotary mower JF-Stoll SB 200 during the alfalfa mowing process, with average yield of 4,5 t ha^{-1} (without irrigation) and average stem height of 73 cm. The aim of the research is to define technical-technological indicators and work quality of the tested mower at the specific working regime. Working swath per samples ranged from 1.83 m up to 1.89 m, averagely of 1.86 m with average coefficient of working swath utilization up to 0.93. Stem incision height ranged within tolerant values for alfalfa (6-8 cm). The average stem cutting height was 6.84 cm (6.23 cm – 7.31 cm per samples. Aggregate mowing speed was in interval from 9.20 km h^{-1} to 12.35 km h^{-1}, averagely 10.80 km h^{-1}. The average total losses were 2.90 % of yield. Losses caused by the cutting height were 1.55 %, whereas the losses caused by stem crushing were around 1.35 % of alfalfa yield Specific fuel consumption was ranged in interval from 2.58 up to 2.64 l ha^{-1}. Bearing in mind the working swath and mowing speed, the tested mower has made the average production output of 1.72 ha h^{-1} at average working speed of 10.80 km h^{-1}.*

Key words: *mower, cutting height, losses, production output*

1. INTRODUCTION

The mowing is the first technical operation performed in the scope of quality cattle food preparation technology. It needs to be done within optimal agronomic term in order to decrease potential negative impacts of external factors.

During the alfalfa hay preparation process, the efforts were made to utilize as much of biological green mass yield as possible in order to decrease potential losses. It is deemed that, in order to maintain fruitfulness, the optimal alfalfa swath height ranges from 6 to 8 cm, i.e. the alfalfa should not be cut under 6 cm. Alfalfa, being good quality livestock feed, plays an important role in nutrition of cuds. It is used for hay preparation (in 90% of cases), silage production, for industrial processing and production of various dehydrated products, and rarely for pasturing [9]. During 2010, about 187.079 ha of alfalfa were mowed in Serbia, producing 1.104.840 t, which makes yield of 5.8 t ha^{-1}[6].

Importance of alfalfa is using for production of high quality feed for all kinds and categories of domestic animals. Furthermore, after several phases of biomass processing, some components of concentrated food for monogastric animals are prepared, [10].

For alfalfa mowing with rotary disc mower [7,8], recommends working speed of 8-15 km h^{-1}. [4], states that the cutting height for rotary mower ranging from 6.9 to 7.33 cm is satisfactory, bearing in mind that alfalfa in our environment is very sensible on cluster damage. In principle, an increase of mowing speed causes proportional increase of cutting height and leads, to increase of hay losses. The occurred are caused by needless high cutting (over 6 cm for alfalfa) and by crushing of the mowed mass-pulverization, since the crushed mass stays on the parcel during hay processing. As known, the greatest amount of crushed mass is consisted of parts of leaves, containing the greatest quantity of nutrients, so the special attention should be paid to this sort of losses. [5], state that rotary disc mower had working speed of 10.14 - 16.52 km h^{-1} during testing process, however, the maximum speed is not recommended due to losses increasing. Total average losses during mower testing process were 3.16% of yield, whereas the maximum production output was 3.17 ha h^{-1}.

Certain authors, such as [1,2], and [3], emphasize the need for mowers construction solutions with regards to simplicity, easy maintenance, functionality and reliability. These are very important factors however, the authors have not dealt seriously with the work quality in their studies.

2. Material and methods

The research was done during a stage of alfalfa mowing process with Stoll SB 200 5 disc rotary mower on the parcel with average alfalfa yield of 4,5 t ha^{-1} (without irrigation). It is noteworthy that the local climatic factors (drought) caused such a low yield, as well as the fact the alfalfa was in blooming phase during mowing process.

The alfalfa green mass yield was determined by measurements taken from a length meter of swath width and calculated per hectare. The mowing machine speed was determined chronometrically. The cutting height was determined on the spot of loss determination, by measuring all sides of appropriate samples surface. The average of each sample is based on the determined parameters.

The alfalfa mowing losses were measured on the surface of one length meter multiplied by real mower swath width on the same place of swath height determination. The total losses are represented as sum of losses caused by the cutting height and crushing process. Determination of the loss was conducted in three samples.

The fuel consumption was measured by the volume method for each sample. The obtained parameters were used for determination of average values for each sample. The measurements of fuel consumption were done exclusively for mowing, and they did not included fuel consumption for other operations, such as flipping, halts, etc. The production effectiveness was defined applying the chronometric method, i.e. by measuring working time of the tested mower at certain moving speeds.

3. RESULTS AND DISCUSSION

The Stoll SB 200 5 disc rotary mower constructive working swath is 2.00 m. The coefficient of working swath utilization during test on adequate samples ranged from 0.91 to 0.94. The average value of constructive was 0.91, table 1. The tendency for coefficient of working swath utilization decreasing was noticed with increasing mowing-machine speed.

Table 1: The achieved working swath, (m).

Type of mower	Working swath	Test			Average
		1	2	3	
Disc mower with 5 discs	Constructive		2.00		
	Achiveded	1.89	1.86	1.83	1.86
	ß	0.94	0.93	0.91	0.93

ß- coefficient of achieved working swath

The average stem cutting height was 6.84 cm at the average moving speed of 10.80 km h^{-1}, (table 2). The lowest cutting height was 6.23 cm at the moving speed of 9.20 km h^{-1}. The highest stem cut was 7.31 cm at the speed of 12.35 km h^{-1}.

Table 2: The stem cutting height, (cm).

Type of mower	Parameter	Test			Average
		1	2	3	
Disk mower with 5 discs	Cut height (cm)	6.23	6.98	7.31	6.84
	Aggregate mowing speed (km h^{-1})	9.20	10.84	12.35	10.80

Averagely, realized losses of Stoll SB 200 5 disc rotary mower were 1.55 % of alfalfa yield, ranging from 1.23 % to 1.88 % ,table 4. With regards to the crushing losses, the tendency of their decrease was noticed by mowing-machine speed increasing. Averagely, the crushing losses were 1.35 % of alfalfa yield, ranging from maximum 1.55 % to minimum 1.07 % of alfalfa yield in sample intervals. The average tests value of total losses was 2.90 % of alfalfa yield in interval minimum of 2.78 % to maximum of 2.95 %.

Table 3: Losses during mowing process, (% of alfalfa yield)

Type of mower	Type of losses	Test			Average
		1	2	3	
Disk mower with 5 discs	Gvr	1.23	1.54	1.88	1.55
	Gus	1.55	1.44	1.07	1.35
	Gu	2.78	2.98	2.95	2.90

Gvr- cutting height losses; Gus- crushing losses; Gu- total losses;

Fuel consumption (Pg) of the Stoll SB 200 5 disc rotary mower was within interval of minimum 3.75 up to maximum 4.92 l h^{-1}, averagely 4.35 l ha^{-1}, table 4. The same mower had the pure effect (W) of average 1.67 ha h^{-1}, thus the average specific fuel consumption (Pg/W) for that mower was 2.61 l ha^{-1}.

Table 4: Fuel consumption for tested mower

Type of mower	Parameter	Test			Average
		1	2	3	
Disk mower with 5 discs	Pg	3.75	4.38	4.92	4.35
	W	1.42	1.67	1.91	1.67
	Psg	2.64	2.62	2.58	2.61

Pg-fuel consumption (l h^{-1}); W-pure effect (ha h^{-1}); Psg-specific fuel consumption (Pg/W), (l ha^{-1});

The production effectiveness is determined by three important factors: moving-machine speed (Vt), swath width (Br), as well as the coefficient of the spent production working time (Ƭpr). The tested mower had the average production effectiveness (Wpr) of 1.72 ha h^{-1}, Table 5, and the used coefficient of the production working time (Ƭpr) of 0,86.

Table 5: The production effectiveness of the tested mower

Type of mower	Parameter	Test			Average
		1	2	3	
Disk mower with 5 discs	Vt	9.20	10.84	12.35	10.80
	Br	1.89	1.86	1.83	1.86
	Ƭpr	0.86			
	Wpr	1.49	1.73	1.94	1.72

Vt=moving-machine speed (km h^{-1}); Br=swath speed (m); Ƭpr= the coefficient of used working time production; Wpr= production effectiveness (ha h^{-1});

4. CONCLUSIONS

Bearing in mind that the acceptable maximum of the total mowing loss is 5 % of alfalfa yield, it is obvious that the Stoll SB 200 5 disc rotary mower has achieved low level of losses.The average losses were 2.90 % of alfalfa yield. However, it is noteworthy that the tested mower has achieved slightly lower coefficient of working swath than the constructive one (0.93). The average cutting height was 6.84 cm, although it is in the scope of optimal value with recommended range for alfalfa mowing of 6 to 8 cm. Specific fuel consumption was in interval from 2.58 to 2.64 l ha^{-1}. Observing the working width and cutting speed, the tested mower made the average production output of 1.72 ha h^{-1} at average working speed of 10.80 km h^{-1}. Based on the presented data of tested alfalfa mower parameters, it can be concluded that there are no significant quantitative and qualitative differences in comparison to the other tested variants of this mowing-machine type. Thus, the results are consistent with the results of other authors, which proves the justification of the use of tested mower.

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Original scientific paper

EFFECTS OF INTERCROPPING ON MICRO ELEMENT CONTENTS OF GREEN BEANS UNDER GREENHOUSE CONDITIONS

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Abstract. *It is one of the techniques that increase total yield and income to cultivate compatible vegetables on the same field at the same time and this is called intercropping. This study, in which beans were cultivated between the rows of tomato, was conducted for three successive growing periods, two in spring (2007 and 2008) and one in autumn (2007) in a research glasshouse at the campus of Akdeniz University. As vegetable species, tomato (Solanum lycopersicon cv.* Selin F1*) and dwarf bean (Phaseolus vulgaris* cv. Gina*) were used and also bean plants were grown alone as a control group. Having been conducted with the aim of determining the effects of intercropping, this study is focused on the micro element contents of the pods of bean. As a result of the statistical evaluations, the differences in results were found to be significant in terms of Fe, Mn, Zn, Cu contents in spring of 2007 and 2008 and in autumn of 2007. According to the research results; in 2007 spring period, the highest value of Mn (33.7 ppm) was determined from intercropping (tomato-bean combination) while the highest values of Fe (254.9 ppm), Zn (19.7 ppm) and Cu (5.8 ppm) were determined in control. In 2007 autumn period while the highest Fe (105.5 ppm) and Mn (33.8 ppm) contents were found in control, Zn (35.5 ppm) and Cu (5.0 ppm) contents also were found in tomato-bean combination. In the last period (2008 spring), the highest Fe (82.6 ppm) and Mn (25.5 ppm) values were determined in tomato-bean combination, while the highest Zn (14.5 ppm) and Cu (1.8 ppm) values were determined in control.*

Key words: *Solanum lycopersicon, Phaseolus vulgaris, intercropping, micro element*

1. INTRODUCTION

The fast increase in world population makes plant production increase even more important with the demand for food. The productivity obtained from unit area should be increased since production fields do not enlarge and even they are reduced day by day [1]. It is one of the techniques that increases total yield and income to cultivate compatible vegetables on the same field at the same time and this is called intercropping [2, 3]. The first important condition for the success of the cultivation in vegetable growing is selection of suitable plants. While such selection varies based on regions and ecologic conditions of those regions, it is also dependent on the Agronomic Interaction among the plants [4].

When intercropping and sole cropping are compared in vegetable production, inputs such as water and fertilizer [5] and field cultivation [6] are used more efficient. Intercropping can increase productivity significantly compared to sole cropping thanks to the efficiency in the use of water, plant nutritional elements and solar energy [6, 7]. Another factor for the success of intercropping is the variations in root zone. Interspecific root interactions affect nutrient mobilization in the rhizosphere and contribute efficiently to nutrient acquisition by intercropping. Intercropping is also effective in improving mobilization and uptake of micronutrients [8, 9]. In another study that was conducted under field conditions in intercropping, the main crop cabbage was intercropped with cos lettuce, crispy salad, radish, onion and pole beans. As a result and development of cabbage wasn’t adversely affected in all combinations except for radish compared to sole cropping [10]. In other study that was conducted by [11], it was found that main crop cauliflower was effective on micro elements Mn and Zn in the intercrop lettuce and that it didn’t make any difference in respect of Fe, Mn, Zn and Cu in case of beans.

In this study that involved intercropping of main crop tomato and intercrop dwarf beans under greenhouse conditions, the effects of intercropping on micro element contents of beans were researched.

2. MATERIAL AND METHODS

This study was conducted under glasshouse conditions at University of Akdeniz, Faculty of Agriculture in Turkey, during Spring (2007 and 2008) and Autumn (2007) growing periods in which beans were grown between the rows of tomato. As plant material, tomato (*Solanum lycopersicon* cv.Selin F1) and dwarf beans (*Phaseolus vulgaris* cv. Gina) were used. Before plants were transferred into the glasshouse, soil samples were taken and physical and chemical properties were analyzed [12] and a fertilization schedule was formed [13, 14]. Analyses of soil samples taken from 0-30 cm depth of the experiment area are given in Table 1.

Table 1. Physical and chemical characteristics of tested soil in greenhouse.

Soil properties	Unit	Values	Assessment
pH		7.4	Slightly alkaline
Calcareous	%	17.1	Heavily calcareous
Salt	%	0.405	Medium/light salty
Texture	%		Clay loamy
Organic matter	%	1.7	Low/medium
Total N	%	0.241	Good
Available P	kg P_2O_5/ha	1349	Excessive
Exchangeable K	kg K_2O/ha	4127	Excessive
Exchangeable Ca	kg CaO/ha	25295	Excessive
Exchangeable Mg	kg MgO/ha	1432	Sufficient
Available Fe	ppm	5.25	Excessive/sufficient
Available Mn	ppm	37.58	Sufficient
Available Zn	ppm	17.22	Excessive
Available Cu	ppm	7.19	Sufficient

While the seedlings of main crop tomato were sown on August 25th for Autumn and on February 10th for Spring, intercrop beans were grown by sowing seeds on April 20th 2007. This date was brought forward for the following Spring and Autumn periods so that vegetation period could be completed and seeds were sown on April 11th and November 5th 2008 by preferring growing by seedling.

Tomato seedlings were planted according to double row system by leaving 100 cm between large rows and 50 cm between narrow rows within-row plant spacing 50 cm. Bean plants were grown in frequency of 20 cm in the middle of tomato rows. As control, bean plants were grown solely according to plantation frequency of 50x20 cm spacing. Plot size was adjusted as 9.75 m^2 and 26 tomato plants in each plot according to plantation frequency of main crop tomato plants. In this study, micro element contents of bean pods were analyzed according to Kacar (1972) for the purpose of determining the effects of intercropping.

3. STATISTICAL ANALYSIS

This study was conducted as three replicates according to random plots during Spring (2007 and 2008) and Autumn (2007) growing periods. SAS package software was used for statistical analysis of results.

4. RESULTS AND DISCUSSION

Effects of cropping systems on micro element contents of bean pods in Spring 2007 growing period are given in Table 2.

Table 2. Effects of cropping systems on micro element contents of bean pods in Spring 2007

Cropping Systems	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Tomato-Bean	220.1 b	33.7 a	13.9 b	3.8 b
Control	254.9 a	26.26 b	19.7 a	5.8 a
LSD	0.3759**	0.7518**	0.5944**	0.3759**

** Different letters within columns indicate statistical differences ($p < 0.01$)

It was determined that there were differences at the level of $p < 0.01$ between cropping systems in 2007 Spring period in respect of micro element contents in beans. While the highest Fe (254.9 ppm), Zn (19.7 ppm) and Cu (5.8 ppm) contents were obtained from solely grown (Control) bean plants, the highest Mn (33.7 ppm) content was found in Tomato-Bean combination.

Effects of cropping systems on micro element contents of bean pods in Autumn 2007 growing period are given in Table 3.

Table 3. Effects of cropping systems on micro element contents of bean pods in Autumn 2007

Cropping Systems	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Tomato-Bean	78.7 b	31.2 b	35.5 a	5.0 a
Control	105.5 a	33.8 a	34.4 b	4.8 b
LSD	0.5343**	0.2711**	0.2671**	0.1611*

** Different letters within columns indicate statistical differences ($p < 0.01$)
* Different letters within columns indicate statistical differences ($p < 0.05$)

It was found out that there were significant differences at $p < 0.05$ level in terms of Cu and at $p < 0.01$ level in terms of Fe, Zn and Mn in 2007 Autumn period between cropping systems. Accordingly, the highest Fe content was found in Control with 105.5 ppm and the highest Mn content was obtained from Control with 33.8 ppm in contrast to 2007 Spring period. The highest Zn and Cu contents delivered different results than 2007 Spring. The highest Zn and Cu in 2007 Autumn period were found in Tomato-Bean combination as 35.5 ppm and 5.0 ppm respectively.

Effects of cropping systems on micro element contents of bean pods in Spring 2008 growing period are given in Table 4.

Table 4. Effects of cropping systems on micro element contents of bean pods in Spring 2008

Cropping Systems	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Tomato-Bean	82.6 a	25.5 a	13.1 b	0.8 b
Control	69.3 b	18.5 b	14.5 a	1.8 a
LSD	0.7518**	0.7518**	0.5944**	0.3559**

** Different letters within columns indicate statistical differences ($p < 0.01$)

It was found out that there were statistical differences at $p< 0.01$ level in respect of Fe, Mn, Zn and Cu contents in 2008 Spring between cropping systems. The highest Fe (82.6 ppm) and Mn (25.5 ppm) contents were found in Tomato-Bean combination whereas the highest Zn (14.5 ppm) and Cu (1.8 ppm) contents were found in Control.

In a study that was conducted in relation to this subject, it was obtained that intercropping was affective on Mn and Zn concentration that was detected in lettuce grown between the rows of main crop cauliflower [11]. It was found that there was no significant effect on Mn, Cu and Zn content when cauliflower and beans were intercropped. In pole beans grown as intercrop between the rows of cabbage were obtained that there was no difference in respect of Fe contents [10].

5. CONCLUSIONS

In this study involved intercropping of dwarf beans between the rows of tomato, sowing and planting dates were brought forward by 10 days in 2007 Autumn and 2008 Spring periods so that vegetation period could be completed in beans in contrast to 2007 spring period. In conclusion, it is estimated that one of the reasons for various results obtained from different periods is dependent on this fact. Another reason for the difference is considered to be such that bean plants in control group elevate micro elements except for Fe from the soil more since air temperature is higher in spring periods. It is foreseen that beans, which were left in the shadow of tomato plants especially in 2007 Spring and 2007 Autumn periods, could receive less Fe content. On the other hand, since tomato plants were contaminated by Tomato Yellow Leaf Curl Virus (TYLCV) in 2008 Spring period, their height was shorter compared to previous periods and it is estimated that the highest Fe content was obtained from Control. In conclusion, it was determined that bean plants planted between tomato rows were affected by shadow and they couldn't make use of nutritional elements, and consequently developmental status of beans was weak.

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Original scientific paper

GREENHOUSE VEGETABLE PRODUCTION ON THE SMALL-SCALE FAMILY FARMS

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Abstract: *In this paper a way of improving the greenhouse production on the small scale or family farms is presented. A new type of round greenhouse construction is introduced that should lead to more energy, economy and ecology efficient vegetable production. Energy efficiency of the spinach and tomato production in the round greenhouse was compared with classical tunnel structure. Results show that, regardless the production surface restrictions, with this type of greenhouse construction financial and energy savings are possible together with the minimization of the plant protection chemical usage. If organic fertilizer is used this type of construction can lead to improved food safety production.*

Key words: *round-shaped greenhouse, tunnel greenhouse, spinach, tomato, energy, energy productivity.*

1. INTRODUCTION

Tomato is one of the most consumed vegetables in the human nutrition. It is used as fresh and, more often in form of sauces. Tomato has high nutrition value and it is rich in minerals and vitamins. World tomato production reaches 2.5 million hectares [1] while in Serbia, tomato is produced on 20 000 hectares [4] with the average yield of 8.3 t ha^{-1}. It is commonly grown in the open filed as well as in the greenhouses. In Serbia, greenhouse tomato production is mostly carried in the plastic tunnels without heating. This production enables two up to three weeks earlier harvesting if compared with the production in the open filed. If tomato is produced in the heated greenhouses harvesting can start in the April [7, 3]. Reasons why tomato is produced in the non heated greenhouses can be searched in high energy consumption [2, 9], high investments in the heating systems and investments in the high productive cultivars.

Spinach is also very common in the human nutrition due to its high nutritive value. It is commonly grown in the greenhouses having the yield of 5 to 25 t ha^{-1}, depending on the production technology. One of the most important characteristic of spinach is that in Serbia region you can find it on the market when market is not so rich in the fresh fruit and vegetables.

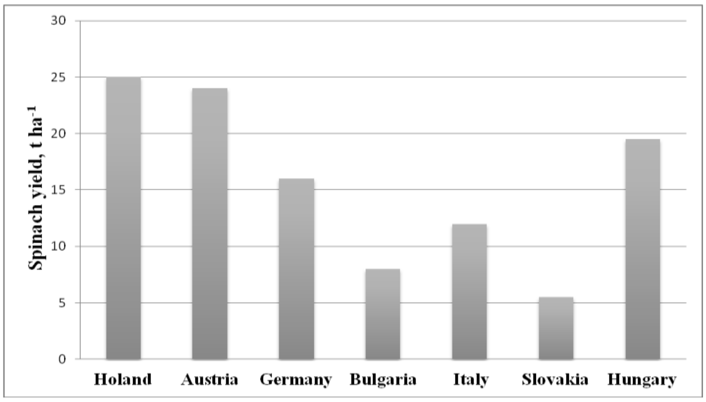

Figure 1 Average spinach yield in Europe

According to the farmers growing of spinach is highly profitable. Its price does not have very small oscillations during the year. The market is huge and current production in Serbia is not enough concerning the human consumption. If it is properly packed and labeled, it can present a significant export potential.

Research in the area of greenhouse construction and its influence on the energy consumption and energy efficiency in the tomato and lettuce production, show that the farmers need to use greenhouses with the higher production surfaces and higher specific volume in order to have optimal production parameters and better overall efficiency [5, 6, 3, 2]. Current economical situation in Serbia and, especially, in its rural regions urged a need of having a greenhouse construction and production technology that would be energy, ecology and economy beneficial for the producers on the small scale farms. The idea of the round-shaped greenhouse construction is not new [11, 10] but it was forgotten due to the previous mentioned reasons of having larger production surfaces. Researchers show that this type of greenhouse is energy efficient providing optimal production condition in sense of good light and temperature distribution which is very important in the winter period of year [7].

Concerning the fact that tomato and spinach are two in a lot of way different vegetables but also two most important vegetables in the human nutrition, the aim of this paper was to analyze the energy efficiency of their production in the open field and in the two greenhouse construction type, tunnel and round-shaped construction.

2. MATERIAL AND METHODS

Spinach production was analyzed in season 2010/11 while tomato production was analyzed for the 2011 summer season. The round-shaped greenhouse (Fig. 2) has its base diameter of 7 m while tunnel type greenhouse has its base of 5.5 x 24 m (Fig. 2). Both of the greenhouses were covered with PE UV IR 180 µm folia. Spinach was seeded in the rows with the inter-row distance was 20 cm. The used seed was Sacata variety. In the tunnel greenhouse tomato was planted with the 2.5 plants per m^2. Variety used was Big Bif. In the round-shaped greenhouse 0.78 plants per m^2 of Amati variety were planted.

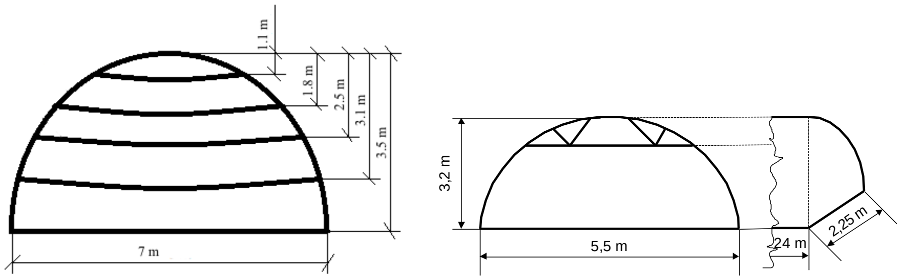

Figure 2 Tunnel and round-shaped greenhouse structure

For production conditions in greenhouse laboratory equipment from the Department for Agricultural Engineering, Faculty of Agriculture Belgrade was used. It consists of data loggers for measuring temperature and relative humidity as well as of the set of solarimeters. Air temperature was measured in the greenhouse and outside of greenhouse. For that purposes WatchDog Data Logger Model 110 Temp 8K, ±0,6 °C was used. Temperatures were measured on the 2 m height in the three different points along the greenhouses. Measuring interval was 10 minutes. Air relative humidity was also measured outside and in the greenhouses. WatchDog Data Logger Model 150 Temp/RH, t=±0.6 °C and RH=±3% was used. Measuring interval was also 10 minutes. For measuring the solar radiation energy WatchDog Data Logger Model 450 – Temp, Relative Humidity was used together with the two solarimeters that have measuring range 1–1250 W m^{-2} and precision of ±5%. Solar energy was also measured on the 2 m height and every 10 minutes.

Energy consumption and analysis were carried using the Ortiz-Chanavate methodology [6, 4, 8]. In this paper results of the microclimatic parameters were show and analyzed as well as the energy efficiency.

3. RESULTS AND DISCUSSION

Temperature and solar radiation measurements show that they are varying depending on the greenhouse construction.

Results show that the solar radiation variations during the day are smaller in the round-shaped greenhouse if compared with the tunnel structure. During the winter spinach production solar radiation energy losses in the tunnel structure were 29.38% while the round-shaped greenhouse was losing 19.51% of the solar radiation energy.

Charts 1 to 4 show daily oscillation in solar energy for the round-shaped and tunnel greenhouse during the spinach and tomato production.

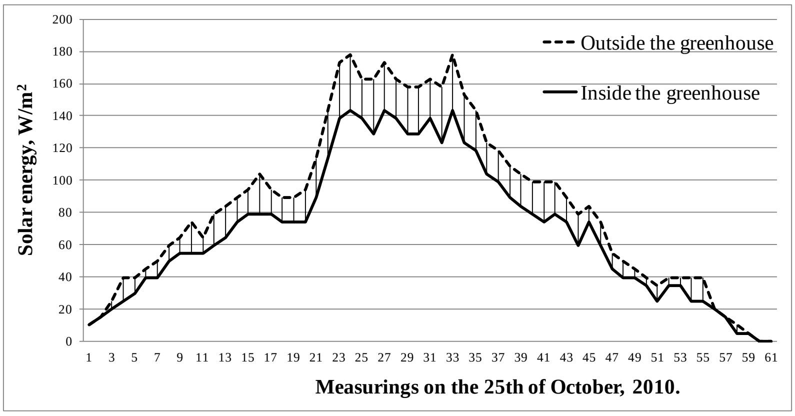

Chart 1 Solar radiation inside and outside the round type greenhouse in spinach production, day time 7.30h till 17.30h

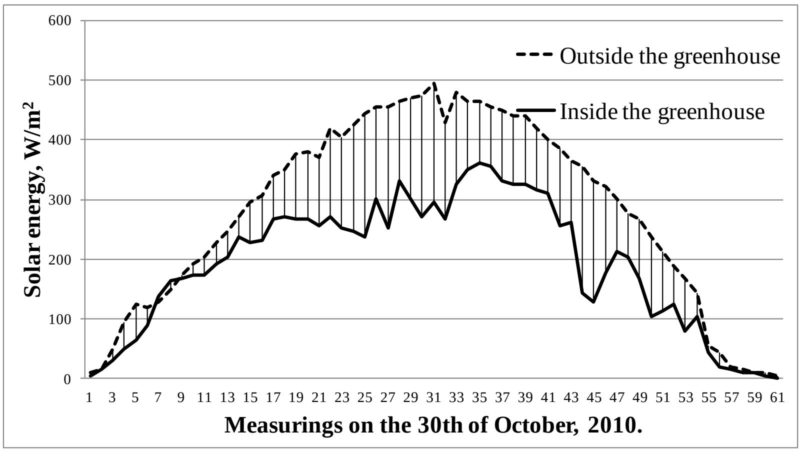

Chart 2 Solar radiation inside and outside the tunnel greenhouse in spinach production, day time 7.30h till 17.30h

It can be seen that with the round-shaped greenhouse construction differences in the outside and transited solar radiation inside the greenhouse are smaller. It can be concluded that this kind of construction has a faster "reaction" to the outside conditions. With the tunnel greenhouse construction it can be seen that these differences are larger and that even if solar radiation increases outside the greenhouse, construction needs some time to react.

During the tomato production similar tendencies were found. Solar radiation transmittance in the round-shaped greenhouse was, in average, 83.22% while in the tunnel structure 56.98% solar energy was transmitted inside the greenhouse.

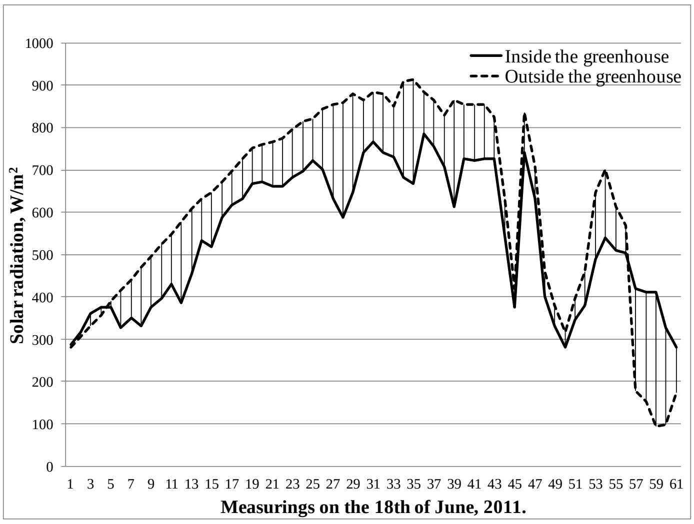

Chart 3 Solar radiation inside and outside the round type of greenhouse in tomato production, day time 7.30h till 17.30h

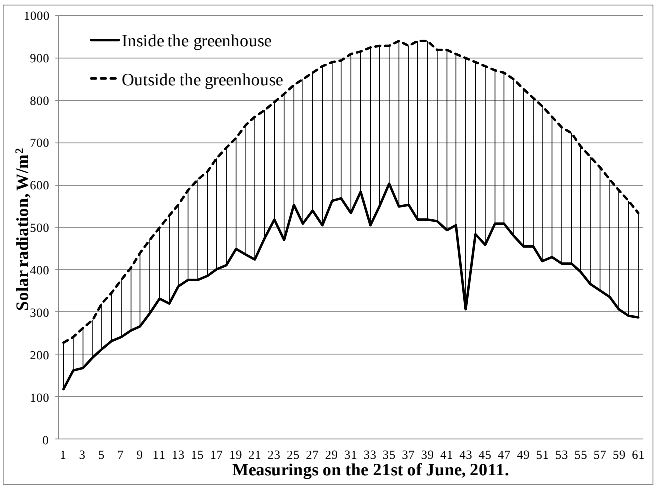

Chart 4 Solar radiation inside and outside the tunnel greenhouse in tomato production, day time 7.30h till 17.30h

Temperature measurements during the winter and summer production seasons show that there are differences in the production conditions in tunnel and round-shaped greenhouse. During the winter spinach production temperatures in both greenhouses were lower inside compared to the outside temperatures during the night and in the early morning hours. In the round-shaped construction greenhouse temperature difference between outside and inside air was 0.2 $^{\circ}$C while in the tunnel greenhouse this difference was 0.6 °C. During the day air temperatures in the greenhouses were higher. In the round-shaped greenhouse this temperature difference was 6.5 °C while in the tunnel structure the difference was 7.35 °C. These differences are lower than 1 °C and are not considered to be important for the plants.

During the summer production temperature inside greenhouses were higher when compared with the temperatures outside the greenhouses during the day. During the night air temperature inside the greenhouses were lower if compared with the outside air temperatures. In the tunnel greenhouse night temperature difference was 0.73 °C while in the round-shaped greenhouse this deference was 0.06 °C.

If energy consumption is analyzed (Tab. 1), it can be seen that there are some differences in tomato and spinach energy balance as well as between the tunnel and round-shaped greenhouse construction.

Table 1 Energy inputs for the tomato and spinach greenhouse production

Energy inputs	Tomato				Spinach			
	Tunnel structure		Round-shaped greenhouse		Tunnel structure		Round-shaped greenhouse	
	Quantity	Energy	Quantity	Energy	Quantity	Energy	Quantity	Energy
Gasoline (l)	3.96	183.35	0.20	9.26	0.90	41.67	0.20	9.26
Electricity (kWh)	46.86	168.70			15.30	55.08		
Nitrogen (kg)	40.42	3181.05	0.71	55.88	3.30	259.71	0.71	55.88
Phosphorus (kg)	26.55	461.97	0.35	6.09	1.65	28.71	0.35	6.09
Potassium (kg)	45.03	616.91	0.71	9.73	3.30	45.21	0.71	8.77
Pesticides (kg)	0.03	5.97			0.19	37.81		
Fungicides (kg)	0.03	2.76			0.01	0.92		
Water (m^3)	22.63	203.67	4.84	43.56	2.22	19.98	0.43	3.87
Technical systems (h)	0.60	7.84	0.25	3.27	1.30	16.98	0.25	3.27
Human labor (h)	170.00	333.20	11.00	21.56	57.00	111.72	11.00	21.56
Total energy (MJ)		5165.42		149.30		617.79		108.69
Specific energy ($MJ \cdot m^{-2}$)		39.13		5.28		4.68		3.85

Based on the direct and indirect energy input analysis it can be concluded that the energy demand in spinach production was lower compared to tomato production. Results show that if round-shaped greenhouse is used significant energy savings could be achieved. In the spinach production energy consumption was 17.74% lower if compared with the spinach production in the tunnel greenhouse. In the case of tomato production this value is even more significant. Specific energy consumption in tomato production in round-shaped production was 5.28 MJ m^{-2} and in tunnel greenhouse 39.13MJ m^{-2} was needed having, in this case energy saving of 86.51%.

Tomato and spinach yield also showed differences regarding the greenhouse construction. Spinach yield in tunnel greenhouse (2 kg m^{-2}) was higher if compared with the round-shaped construction greenhouse (1 kg m^{-2}). Similar tendency was observed for the tomato production. In the tunnel greenhouse tomato yield was 12.5 kg m^{-2} while in round-shaped greenhouse achieved yield was 7.43 kg m^{-2}. Tomato yield was also analyzed concerning the yield per plant. Results show that in the round-shaped greenhouse 10 kg of tomato were obtained per plant while in the tunnel 5 kg were obtained per plant.

Energy analysis (Tab. 2) shows that there are significant differences in energy production parameters for round-shaped and tunnel greenhouse in the, both, tomato and spinach production.

In the case of tomato production 77.32% less energy was needed per kg of tomato if compared with the tomato production in the tunnel greenhouse. Energy ratio was also higher in the case of tomato production in round-shaped greenhouse. Energy productivity was significantly higher in the case of round-shaped greenhouse. Yields were lower but also energy input. In the tomato production in round-shaped greenhouse less chemicals were used. In this way small scale farmers can be marked-orientated producing quality and healthy food.

Table 2 Energy analysis for the tomato and spinach production in the greenhouses

	Tomato		Spinach	
	Tunnel greenhouse	Round-shaped greenhouse	Tunnel greenhouse	Round-shaped greenhouse
Specific energy input ($MJ \cdot kg^{-1}$)	3.13	0.71	2.34	3.85
Energy ratio	0.26	1.13	0.26	0.16
Energy productivity ($kg\ MJ^{-1}$)	0.32	1.41	0.43	0.26

In the spinach different results were obtained. Lower yields were obtained in the round-shaped greenhouse construction and this caused higher energy input per kg of spinach, as well as lower energy ratio and energy productivity. For one kg of spinach 3.85 MJ of energy was used in the round-shaped greenhouse which was 39.22% higher if compared with the spinach energy demand in tunnel greenhouse.

In the round-shape greenhouse energy ratio and energy productivity were 38.46% and 39.53%, respectively, lower when compared with the tunnel structure. The main reasons for such results are lower yields in the round-shaped greenhouse. Concerning the spinach yield in Europe (Fig.1) spinach yield in both greenhouses can be considered very low. Reasons for lower spinach yield cannot be searched in the production conditions concerning the fact that temperature and solar radiation in the round-shaped greenhouse were better if compared to production condition in the tunnel structure.

Based on the presented results it can be said that round-shaped greenhouse construction can be suggested as energy beneficial in case of intensive plant production, such as tomato. Regarding the production conditions, ecology and production surface, round-shaped greenhouse construction can be proposed to small scale farmers as economically, energy and ecology beneficial solution.

4. CONCLUSIONS

Greenhouse production is one of the most intensive branches in agriculture. It is intensive in sense of high yields, year-around production and high energy consumption.

Rural areas are in a very difficult situation in sense of economy and energy. The aim of this paper was to show the possibility of using simple and cost effective greenhouse construction that can ensure energy and economy sustainability of the small-scale family farms in the rural parts of Serbia.

The proposed round-shaped greenhouse construction showed good results regarding the production conditions in the winter production of spinach and summer tomato production. Concerning the energy sustainability this construction is good solution for summer tomato production. Reasons for lower energy efficiency in the winter production of spinach can be searched in the variety of spinach or in smaller quantities of fertilizer applied. Further research will be concentrated on energy analysis of different vegetables production in order to have a better picture of energy, ecology and economy feasibility of this kind of greenhouse construction in the vegetable production on the small-scale family farms.

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Original scientific paper

THE EFFECTS OF SOME AGRICULTURAL WASTE COMPOST APPLICATIONS ON SOIL MACRO NUTRIENT (N, P, K, Ca, Mg) CONTENTS

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Abstract*. The wastes emerge at the end of the agricultural production and they are being eliminated without any care and concern. Cut flower carnation cultivation and mushroom production are carried out in Antalya (Turkey) region for a long time. As a result of these productions great quantities of organic waste (carnation wastes and spent mushroom compost) occur. In this study; some agricultural wastes are composted with different proportions and organic additives by mixing. Composts were added in soils for growing (standard) carnation. In this article the effects of compost and organic material on macro nutrient (N, P, K, Ca, Mg) contents of soil were evaluated. With the organic material and compost application in soil, the macro nutrient contents of soils were found to be statistically significant ($p<0.001$). The effects of organic materials on nutrient contents in soils provide positive relation for vegetable production.*

Key words: Compost, Spent mushroom compost, Carnation wastes, Nutrient contents.

1. INTRODUCTION

Together with the increasing vegetable production, an increase is observed in the waste quantities. It is known that the most important problem in greenhouse production was the produced wastes [1]. Several vegetable origin wastes occurred after agricultural production and these wastes are utilized in various ways (composting, biogas, burning etc.). Some of the agricultural production wastes that come about in Antalya region, where agricultural production is predominantly performed, include greenhouse vegetable wastes, cut flower wastes, grass wastes, horticulture wastes, banana plantation wastes etc. In a study, it is reported that approximately 330.625 tons of greenhouse plant wastes in the province Antalya are being randomly disposed or terminated by burning [2]. For this reason, agriculture-originated organic wastes should be utilized in useful ways. Organic fertilizer can be obtained by ensuring recycling by means of composting that is one of the best utilization methods for organic wastes. Composting is the process of obtaining a soil regulator product with a fertilizer value by degrading the organic wastes under oxygen (aerobe) conditions with microorganisms [3, 4, 5]. In composting, optimum C/N ratio should be 30/1, optimum humidity content should be between 30-60% and pH should be around 6.5 – 7.5 for microbial decomposition [6].

Organic materials are important soil additives, particularly in semiarid regions (such as Turkey) where there is a low input of organic materials. Use of organic matter in arid and semi-arid regions, where soil organic matter (SOM) content is rather low, can contribute to enrich the soil with SOM. The gradual and rapid decrease in SOM content in soils under intensive agriculture practices, especially in those having hot climates, may lead to the deterioration of their chemical and physical properties [7]. The soils of Turkey are generally poor concerning the organic material contents and the ratio of soils containing organic materials at a ratio lower than 2% is around 69% which is a very high share [8]. The organic material deficiency in soils can only be reinforced with organic fertilizer applications and this causes serious economical problems.

This study is conducted to determine some agricultural wastes composted in Antalya region where an intensive greenhouse production is practiced and where large agricultural waste volumes occur.

2. MATERIAL AND METHODS

In the experiment 127 l cylindrical PVC reactors were used for purpose of composting. The reactors were isolated with 50 mm glass wool. Their dimensions were 0.80 m in height and 0.40 m in diameters. Perforated floor (#5 mm) was used at the bottom of each reactor to hold material and distribute air equally. Air was supplied with radial fan controlled with an on/off timer with a 15 min on and 45 min off work schedule for all experiments (Figure 1). Composting process was performed under controlled conditions and composts were kept waiting for maturation phase at the end of the pre-composting process.

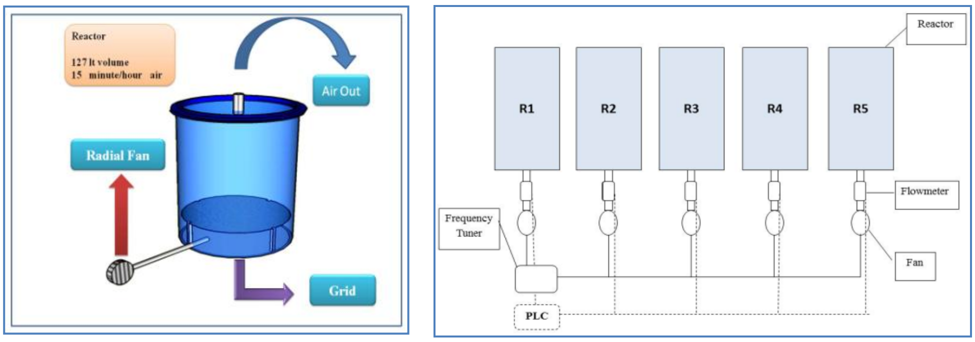

Figure 1. Properties of container composting reactor

In the study, carnation plant wastes, spent mushroom compost, poultry manure and cattle manure were mixed and composted in varying ratios (Table 1).

Table 1 Mixture ratios in the composting reactors

Reactor No	Carnation Waste Ratio (%)	Spent Mushroom Compost Ratio (%)	Poultry Manure Ratio (%)	Cattle Manure Ratio (%)
R1	75	25	-	-
R2	50	50	-	-
R3	25	75	-	-
R4	50	25	25	-
R5	50	25	-	25
R6	25	25	25	25
R7	100	-	-	-

All composts were added into pot soils taking into account humidity contents in such a way that 1 ton ha^{-1} and a vegetation period of approximately 11 months were determined. Furthermore, there was a control application (without organic material application) with only chemical application. All applications were treated with chemical fertilizer in limited ratio.

The study was carried out in a completely randomized plot design with four replications and conducted under greenhouse conditions as a pot experiment. Standard species (Lia) carnation seedlings were planted in pots in such a way that four carnation plants were placed in each pot. All of the necessary cultural processes were performed during the vegetation period and experiment was finalized and plants were harvested and taken to the laboratory for analysis.

Soil samples were taken from the pots in the beginning of the experiment. Soil samples were analyzed for physical and chemical properties. The soil used in the experiments was chemically analyzed after they had been air-dried and passed through a 2 mm sieve. Total carbonates were determined according to the calcimeter method of Nelson [9]. Soil organic matter by the Walkley- Black [10]. Soil pH (Jackson 1967), EC EC was determined according to Anonymous [12]; Total N was determined by modified Kjeldahl procedure [13]. Extractable P content was extracted by $NaHCO_3$ [9] and determined by a molibdate colorometric method [11]; extractable K, Ca and Mg were extracted with NH_4-OAc and determined by atomic absorption spectrophotometry (AAS) [13].

In compost and organic materials, organic carbon [14], organic matter content [10], pH [15], nitrogen [16], phosphorus [17]. K, Ca, Mg, Fe, Zn, Mn and Cu [18] were determined by preferred analysis methods.

Statistical Methods

The experiment was arranged in randomized complete plot design with four replicates of four plants in each plot. All data were subjected to analysis of variance and a significant ($p<0,05$) F ratio detected for treatment effects, a least significant difference (LSD) value calculated by 5 % (MSTAT-C packet program).

3. RESULTS AND DISCUSSION

This study was evaluated some agricultural wastes by composting and then these composts were added in soils. The results of physical and chemical of soil and composts are given in Table 2 and Table 3.

Table 2 The results of physical and chemical properties of soil

N	P	K	Ca	Mg	pH	$CaCO_3$	EC	Org. Matter
%	mg kg^{-1}	me $100g^{-1}$				%	dS m^{-1}	%
0.039	4.136	0.046	0.33	11.8	7.95	43	0.37	0.90

The physical and chemical properties of composts that were added in soil are given in table 3.

Table 3 The physical and chemical properties of composts

Analysis	R1	R2	R3	R4	R5	R6	R7
pH	8.32	8.10	7.85	8.52	8.19	7.85	8.89
EC (dS m^{-1})	4.46	4.76	3.64	3.50	3.84	3.65	3.41
Org. Matter %	57.9	33.4	33.8	32.1	33.5	29.8	63.1
C/N	19.98	9.98	10.20	8.49	8.50	8.45	24.34
N (%)	1.61	1.86	1.84	2.10	2.19	1.96	1.44
P (%)	0.55	0.59	0.56	0.45	0.48	0.49	0.45
K (%)	2.41	0.94	0.84	0.80	1.15	0.75	3.13
Ca (%)	3.17	2.91	3.23	2.91	2.12	2.97	3.03
Mg (%)	0.37	0.32	0.66	0.25	0.32	0.29	0.27

In respect of macro nutritional elements all applications were found to be statistically significant ($p<0.001$) and demonstrated increase compared to control. The effects of compost applications on total nitrogen content of soils were found statistically important ($p<0.001$) and the highest value was obtained from R1 application. Compost applications led to the increase of soil total nitrogen contents of soil as compared with the control soil. With the added organic matter in soils, the contents of N in soil can be increased. The nitrogenous compounds that are released due to the mineralization of organic matter are used as essential nutrients by plants (19, 20).

The highest value of the soil available phosphorus content was achieved from R1 application, while the highest value soil exchangeable potassium content was observed in cases of R1 and R5 applications. The effect of soil organic matter on soil phosphorus content is quite high (20). Therefore, when the organic matter is added in soil, total and available soil phosphorus contents increase.

The highest value of the soil exchangeable calcium content was achieved from R1 application and the highest value of the soil exchangeable magnesium content was achieved from R6 application. In all applications, the lowest values were observed on control application (R8). Demir and Çimrin (21) reported that with the addition of organic matter, the content of soil exchangeable calcium and magnesium increased significantly. Similarly, Moran and Schupp (22) reported that soil magnesium content increased with apple pomace application that apple pomace was composted.

Table 4 The effects of compost and organic materials on soil macro element contents[1]

Applications	N %	P mg kg^{-1}	K me $100g^{-1}$	Ca me $100g^{-1}$	Mg me $100g^{-1}$
R1	0.111 **a**[2]	47.19 **b**[2]	1.38 **a**[2]	25.56 **a**[2]	4.62 **ab**[2]
R2	0.083 **bc**	40.34 **c**	1.03 **ab**	24.44 **ab**	4.71 **ab**
R3	0.097 **b**	35.80 **cd**	0.93 **d**	23.73 **b**	4.61 **ab**
R4	0.078 **cd**	48.72 **b**	1.14 **bc**	24.42 **ab**	4.63 **ab**
R5	0.090 **b**	45.94 **b**	1.34 **a**	24.36 **ab**	4.72 **ab**
R6	0.088 **bc**	67.78 **a**	1.19 **b**	24.55 **ab**	4.89 **a**
R7	0.093 **b**	34.32 **d**	0.62 **e**	24.24 **ab**	4.48 **bc**
Control	0.063 **d**	12.77 **e**	0.46 **f**	23.16 **b**	4.22 **c**
LSD (%5)	***	***	***	***	***

1Values of n=4; *, significance; *, p<0.05; ***, p<0.001.
2The difference between values not shown with the same letter are significant at a p<0.05 level.

4. CONCLUSIONS

This study was conducted with the aim of demonstrating the possibility of utilizing different agricultural organic waste materials. Due to the abundance of organic material variety and lack of sufficient experience in the utilization in agricultural fields, different mixtures shall be formed and composted and utilization of such composts can be increased in agricultural fields. Carnation plant wastes and spent mushroom compost are potential organic wastes that can be found in great volumes in the province Antalya and they ensure significant increases in plant development when they are composted together.

The results of the investigation showed that the macro element contents in soils increased all compost applications. The mixture ratios of %75CW+ %25SMC (R1 application) and %25CW+%25SMC+%25PM+%25CM (R6 application) were the applications that yielded the best results in many parameters despite the increases in other mixtures compared to the control group. Since the utilization of organic waste materials, waste materials will no longer be a problem and this will increase the amount of organic materials and fertility parameters that are useful for soil.

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Original scientific paper

RESEARCH OF GREEN PEAS COMBINE HARVESTERS

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Abstract. *Complex mechanization in green peas production presumes to have mechanized process of harvesting as one of a crucial assumption for quality of seed material refinement.*
This study presents the results of research working parameters of two types of green peas harvesters in the Republic of Serbia.
This article is summary of results observed in machine exploitation and presents some parameters of a importance for working quality.
Working quality and exploitation parameters were observed in dependence on machines operating mode and crop conditions.
A comparative analysis of exploitation parameters of these harvesters was completed. Based on that analysis, we determined directions for future using of these harvester types.

Key words*: Pisum sativum L., Green peas, Stripping harvester, Working quality, Losses.*

1. INTRODUCTION

Green peas (Pisum sativum L.) has a tradition in Serbia as a processing crop. Short growing season, known system of production, a fully mechanized production, high nutritional value, continuous demand in the domestic and international markets stimulate production and consumption of peas.

From different types of edible peas (*Pisum sativum* L.), the family Fabaceae (Leguminosae), the most common is the green pea *Pisum sativum* var. *sativum* L. This pea has a tough pod, which is discarded prior to using.

The pea varieties can be classified into the categories: market peas, from which pods are harvested for consumption as a fresh vegetable; and vining peas, for canning or freezing [3].

Green peas are an important crop because they provide growers with greater revenue than alternative spring grain crops. As a rotation crop with winter cereals, green peas break the disease and weed cycle, conserve soil moisture relative to other rotational crops, improve soil fertility by fixing nitrogen, and increase yields in the next crop planted.

1.1. Green peas production

World production of green peas is currently estimated to be 17 million tons. The primary areas of production are the China (10.3 Mt), India (3.6 Mt) and Europe (1.8 Mt; of which United Kingdom produces 0.4 Mt). According to the production of peas Serbia is the twentieth in the world (Table 1).

At the Republic of Serbia green peas participates with 1.9% in the structure of European production, and is located in 12th place, while in the the world at the 20th place [5].

According to realized annual consumption of 2 kg per capita, the Republic of Serbia is situated near the top of European annual consumption. The average green peas yield is about 3 t/ha, which is almost 7 tons less than the European average.

Table 1 World production of green peas [5]

Rank	Area	Production (t)	Rank	Area	Production (t)
1	China	10274324	11	Peru	100834
2	India	3571000	12	Hungary	99118
3	United Kingdom	424723	13	Italy	99039
4	United States of America	267550	14	Pakistan	98680
5	France	262935	15	Spain	84104
6	Egypt	225689	16	Russian Federation	72570
7	Algeria	145000	17	Belgium	64428
8	Morocco	123153	18	Guatemala	47600
9	Kenya	115000	19	Mexico	47077
10	Turkey	103787	20	Serbia	41204

Production completely satisfies the needs of domestic consumers, so that pea is an important export product that has a good perspective on the international market, and this increasing export provides the basis for further expansion of agricultural production in the Republic of Serbia [7].

Vegetables are grown in Serbia at about 270,000 ha, which represents 9 % of the total arable land. The average area under green peas is 13,000 ha, with a tendency to decrease (Table 2). Within the structure of area under vegetable peas are grown on about 5 %.

Table 2 Characteristics of green peas production in the Republic of Serbia [18]

Year	Green peas		
	Harvested area, ha	Total yield, t	Yield per unit, kg/ha
1947	3006	2940	978
1950	4983	3110	624
1960	4831	7000	1448
1970	8889	10440	1174
1980	9961	10270	1031
1990	11479	11920	1038
2000	13126	22775	1735
2007	13149	35384	2691
2008	13960	42058	3013
2009	13481	38895	2885
2010	13258	36733	2771
2011	13928	41204	2958
2012	12384	32697	2640

In recent years in Serbia yield of green peas is constantly increasing, and it is about three tons per hectare, although the 2012th decreased due to drought.

1.2. Green peas harvesting

Green peas as factory crops are usually harvested in a single phase, whereas crops for the fresh market are generally harvested over a three-week period.

Factory crop yields vary from a conventional 1.5 tons to a good yield of over 5 tons of peas per hectare. Average yields are 2.5 to 3 tons per hectare [18].

Factory crops are normally mechanically harvested at a stage when much of the crop has reached the edible maturity, but before the first grains become hard and starchy. The timing of harvest is critical. The sugars in the grains are converted to starch fairly quickly, especially when exposed to high temperatures, so rapid processing is essential.

Manual harvesting of vegetables accounts for 30 to 60% of the total production costs [16], with a high net share in the final price of the product. Therefore, mechanization of harvest operations has a high potential for input reduction.

Green peas intended for the fresh market are normally harvested 50 to 80 days after planting depending on the variety and growing conditions. One person can harvest 320 to 550 kg of peas per day depending on yield and growth habit. It requires approximately one hour to pick 27 kg of peas [10]. About 250 man-hours are required to harvest an hectare of peas. The expected yield of peas per hectare is approximately 7 t. If peas will be machine harvested, select a bushy, nonvining variety with sets of pea pods concentrated above the foliage.

Harvesting is the responsibility of the contracting processor's field representatives [11, 12]. The processor provides and schedules equipment needed for harvesting. Recent improvements in harvesting have been achieved through larger combine harvesters and a shift toward use of pod-stripping harvesters.

Peas are harvested 24 hours a day to make best use of expensive equipment and to be able to supply a constant volume of product to processing plants. Delivering peas to the factory as soon after harvest as possible is very important, to minimize damage from heating and subsequent loss of quality.

Peas are harvested at about a (90-150) 100 tenderometer reading [4]. At a lower than optimum tenderness a higher price is paid, while at a higher than optimum tenderness a lower price is paid.

Green peas are one of the most perishable vegetables. They pass rapidly through the optimum stage of maturity during hot, dry and windy weather. A delay of 1 to 2 days in harvest may result in greater yields but can cause a reduction in pea grain. Green pea harvest begins in June and usually ending in early August. The optimum harvest time is when pods are filled and the peas are still soft and relatively immature. Generally, those areas with higher precipitation or irrigation produce higher pea yields.

Many requirement have to be improved in order to satisfy the developing needs of growers, processors and feed manufacturers.

1.3. Literature review of harvesting green peas

Glancey [9] in his studies has came to the conclusions: trash content in the harvested product with an overall average of 15.2%; total field loss with an average loss of 10.4%; the header of the combine participates with averaging 70.3% of the total field loss.

Glancey [8] researched the productivity of the combine harvesting of green peas in order to determine the loss of header picking device. When this is followed by forward speed and speed rotations of picking rotor. The results showed that the optimal combination of 2.1 km/h and 205 min^{-1} for speed combine and picking rotor, respectively, which resulted in minimal losses picking device of 2.03% of the pea yield.

Serbia has great potentials and is going expansion of industrial vegetable production of peas. The condition and perspectives of the mechanization for the vegetables harvest shows that the pea harvesters most represented, there are 35 self-propelled peas combine harvesters, 10 green bean combine harvesters and 13 sweet corn combine harvesters [13]. An average age of the peas combine harvesters until 2007 was 16 years, while a certain number of combine harvesters was technically amortized.

Bajkin [2] researched four models of green peas combine harvesters (Herbort-462, Shelbourne Reynolds SB-8000, FMC-679 and Ploeger EPD-490). The investigated combines achieved the area effeciency of 0.35-0.64 ha/h and mass effeciency of 2.52-3.53 t/h of grain. Grain losses amounted of 5.12-23.9 %, grain damage amounted of 3.83-13.6 %, while the content of foreign ingredients amounted of 0.74-7.09 %.

Bajkin [1] has explored harvester to harvest green peas FMC 979-AT, which achieved an average mass effect of 7.74 t/h. Under the same conditions, combines the older generation, Herbot-461 achieved the mass effect of 1.10 t/h, and combine FMC-679 from 1.5 to 1.78 t/h.

Stanimirović [17] in his work states that the highest losses in unharvested pods were recorded in early maturity cultivars on extremely uneven ground (17.34% of average yield) because of the uneven terrain on the grounds. The best threshing quality performance was achieved at 300 rev/min of the drum, with lowest grain losses and grain damage being 1.1-1.8% and 0.9-1.2% respectively. During this operating mode, thresher losses in unthreshed pods were 8-9%.

Findura [6] is examined the green peas combine harvester Ploeger EPD-490. Based on the experiment, it was concluded that when working at a lower speed (2.2 km/h), a higher percentage of whole grains was achieved (84.6 %). The increase of operating speed to 2.9 km/h caused an decreases percentage of whole grains by 4.3 % and increased presence of damaged grains by 1.2%, compressed grains by 1.22% and the content of residues was increased by 1.88%.

2. MATERIAL AND METHODS

In this paper two green peas harvesters were examined, Ploeger EPD-538 and FMC-979-AT, which are generally differ in the construction of thresher. These harvesters were studied at various working velocities and pea maturity stages. Losses and grain condition were monitored for each combination.

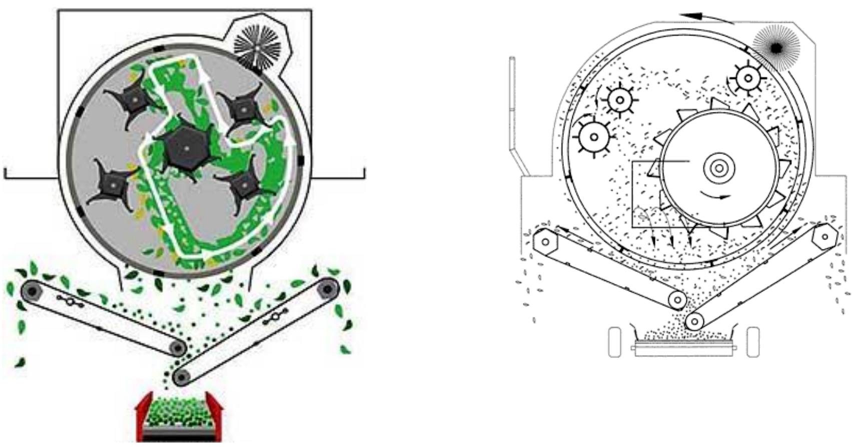
Mechanized harvesting of vegetables intended for processing can be considered generalized and economical in industrial countries. This includes specific problems like: enormously variable of products to be harvested regarding agronomical, physiological and structural characteristics; very specialized harvester and a low number of working hours in a year; adequate varieties, planting systems and scheduling, soil and irrigation management, materials handling, grading and sorting, processing, which impose strict conditions on the viability of mechanical harvest of vegetables[16].

Pea harvesters strip the pods from the plants, and then remove the peas from the pods. About 5 to 10 % yield loss occurs during the mechanized harvest. As green peas increase in size, they decrease in quality by becoming less succulent. Smaller size peas grain pass through the combine screens and are not retained.

2.1. Technological characteristics of the researched green peas harvesters

Object of our research were the two self-propelled combines for harvesting green peas. Contemporary combine harvesters for green peas have almost the same working principle. On the header there is less difference, while thresher has more differences in construction. In practice there are treshing devices for with two, three, four and five rotors.

The figure 1 below shows the thresher construction of researched combine harvesters, PMC - 979 AT and PLOEGER EPD - 538, and in Table 3 are shown their basic technical characteristics.



a) PMC - 979 AT [15] b) PLOEGER EPD - 538 [14]

Figure 1. Section view of researched green pea harvesters thresher

Threshing is a separation procedure uses a rotating drum to remove peas from pods. Friction is used to separate the pea grain from their pods. Friction is applied by slow-rotating rubber rollers against a drum, also itself rotating, that behaves as the concave, as it sieves the peas through it. From there, peas are cleaned by air, conveyed and loaded to bins.

Table 3 Basic technical characteristics of researched green peas harvesters

Characteristics	**PMC - 979-AT**	**Ploeger EPD-538**
Main dimensions (mm): - Length - Width - Height	 11975 4000 4000	 11000 3999 3999
Weights (kg):	26120	22600
Engine - Type - Cooling - Power (kW)	 Deutz TCD-2015-v06 Liquid-cooled diesel 300	 Deutz TCD-2015-v06-4v Liquid -cooled diesel 300
Fluid capacities (l) - Fuel - Hydraulic oil	 775 550	 950 350
Transmission	Hydrostatic	Hydrostatic
Vehicle speeds (km/h) - Road - Field	 25 9	 26 7.1
Hopper capacity (kg)	1900	2200
Levelling (%) - Front to rear - Side to side	 15 18	 12 18

The total working quality of the harvesters was evaluated by sampling peas grain from the storage bin.

Losses of header were taken after the passage of the combine, samples were collected inserting a foil, area 2 x 3 m^2, behind the header.

The foil separates the losses that occurred at the header from the other sources of loss (threshing and cleaning system losses) as the harvester passed over the foil.

Losses under a foil were picked up and placed into one of separate categories: loose pods and loose peas grain.

Test runs for each speed combination were repeated at twice in a field resulting in loss for each of the loss categories at each combination of speeds.

2.2. Location of the experiment

This research was performed in the months of May and June 2008. Field experiment was located on a plot T25A, area 68 ha, and plot 300B, area 98 ha, the chernozem soil type for both plots, at farm PD "Halas Jozef" in the area of town Ada, in northern Serbia.

On the researched plots were sown varieties of pea: Avola, on the plot T 25A, and Omega on the plot 300 B. On the plots was different values of tenderometric values, 120 TV on the plot T 25A, and 190 ^{o}TV on the plot 300 B.

Crop condition was determined in five samples, before the start of the harvesting samples were taken from 1 m^2, diagonally taken at the plot to determine the total yield.

2.3. Description of operations in green peas production

Green peas was grown following winter wheat or spring barley.

The soil preparation of plots for growing of green peas is compatible with the principles of conventional tillage.

Before plowing is done the distribution of mineral fertilizer.

Cereal stubble that is fall plowed or chiseled is cultivated in the spring for weed control followed by herbicide incorporation. The crop is then seeded and the ground harrowed and rolled.

Optimal seeding rate vary with the green pea variety, but is usually average 200 kg/ha. Green peas was drilled in rows 15 cm apart.

Pea sowing are scheduled over an eight-week period from March to April. Pea sowing was performed in month March.

Chemical treatment was performed using the sprayer against broadleaf weeds and against aphids.

Irrigation was performed with irrigation device of type center pivot. Peas was irrigated in five cycles per 20 mm of water.

3. RESULTS AND DISCUSSION

Grain yields of harvested peas was reached values 7.18 t/ha on the plot T 25A and 5.12 t/ha on the plot 300 B.

Losses incurred in the harvesting of green pea were observed on the header and thresher of harvesters.

The lowest average total grain losses amounted to 8.47 % of the total yield, at the plot T 25A (tenderometric value 120 °TV), while at the plot 300 B (tenderometric value 190 °TV) amounted to 10.76 %.

Header losses made up of uharvested pea pods were induced by length of the growing season of individual cultivars and ground evenness. Grain losses in unharvested pods increased with an increase in the size of microdepressions in the ground. The highest losses in unharvested pods were recorded in early maturity cultivars on extremely uneven ground (17.34% average yield).

Table 4 presents the yields, losses and grain quality in the bin, depending on the plot and working velocities.

Table 4. Quality of peas grain in the storage bin of the researched harvesters

	Tendero-metric value (° TV)	Working velocity (km/h)	Grain yield (kg/ha)	Total losses (kg/ha)	Whole grains (%)	Damaged grains (%)	Broken pods (%)	Pods, plants residues, soil (%)
EPD-538	120	2.48	7179	608	93.57	3.62	2.62	0.19
EPD-538	120	3.35	7179	653	88.91	4.70	4.85	1.54
FMC-979-AT	120	1.96	7179	1046	85.16	5.64	5.33	3.87
FMC-979-AT	120	2.45	7179	1128	84.96	5.87	4.68	4.49
EPD-538	190	3.22	5120	551	98.23	0.38	0.29	1.10
EPD-538	190	4.03	5120	579	95.76	0.83	1.18	2.23
FMC-979-AT	190	2.40	5120	910	96.74	0.72	0.5	2.04
FMC-979-AT	190	3.05	5120	972	92.84	1.14	1.66	4.36

Grain cleanliness was expressed in a high percentage, from 84.96 to 98.23 %, whereas the difference in tenderometric values did not have more influence on the result, ie, separation systems are performed their task very well. Contaminated grains of green peas present higher requirements for cleaning and sorting in the plants, and it increases the production costs.

Table 5 shows the average value of losses for the researched harvesters Ploeger EPD - 538 and FMC - 979 AT, depending on tenderometrc values and different operating speeds of combine.

At the plot T 25A (tenderometric value 120 °TV) research findings clearly show that the largest losses for both types of pea harvester, for all velocities, was header losses in the category pea pods, about 70.37 to 75.31 % from the total losses. At the plot 300 B (tenderometric value 190 °TV) the average header losses was 52.07 to 64.83 %, of which have been equally present losses of grain and pods, per about 30 %.

The tresher losses at the plot T 25A have had value of 9.73 to 18.65 %, and at the plot 300 B, amounts are much higher, 35.17 to 47.93 %.

Table 5. Average losses of pea harvesters from the total losses

	Tendero-metric value (° TV)	Working velocity (km/h)	Header losses grain (%)	Header losses pods (%)	Total header losses (%)	Thresher losses grain (%)	Thresher losses pods (%)	Total thresher losses (%)
EPD-538	120	2.48	13.24	75.31	88.55	6.30	5.15	11.45
EPD-538	120	3.35	12.42	77.85	90.27	4.07	5.66	9.73
FMC-979-AT	120	1.96	5.33	76.02	81.35	6.23	12.42	18.65
FMC-979-AT	120	2.45	15.86	70.37	86.23	4.81	8.96	13.77
EPD-538	190	3.22	34.18	24.76	58.94	20.94	20.12	41.06
EPD-538	190	4.03	37.57	27.26	64.83	16.44	18.73	35.17
FMC-979-AT	190	2.40	23.23	28.84	52.07	18.34	29.59	47.93
FMC-979-AT	190	3.05	27.16	35.32	62.48	17.04	20.48	37.52

The difference in the amount of researched harvesters losses can be explained by the fact that the harvester FMC - 979 AT was manufactured 2002nd year, while harvester Ploeger EPD - 538 2008th year. There is definitely an obvious difference in the technological level of construction and level of reliability in exploitation.

4. CONCLUSIONS

The working quality research of two different for green peas harvesters leads to several conclusions.

Grain yields of green peas, whose value ranged from 7179 to 5120 kg/ha, and crop condition significantly affected to the working quality of the researched harvesters.

In the work of both combines, with the increase of operating speed, regardless of the tenderometric values, 120 to 190 ^{o}TV, total losses of green peas grow, with values in the range 8.47 to 18.98 %.

The measured losses in the harvest of green peas, at harvester FMC - 979 AT ranged from 14.57 to18.98 %, and at harvester Ploeger EPD - 538 from 8.47 to11.31 %.

From the results of this research it can be concluded that by increasing the speed of the harvester and tenderometric values was coming to increasing the amount of total losses and pollution, particularly was evident to increasing losses on the header, in both cases.

The research results show that, except for speed of operation and construction characteristics of the harvester, to the quality of work affecting and other factors such as the status of the varieties, the quality of soil preparation, sowing quality and others, which should be monitored in the further complex researches.

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Original scientific paper

INFLUENCE OF GREEN BEANS GROWING TIME ON MECHANIZED HARVESTING EFFICIENCY

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Abstract. *Successful green bean production involves scheduled sowing to maintain continuous supply through the harvest period, and timely harvesting when beans are prime quality.*
Machine harvest is the only way to efficiently pick the required green beans quantity. However, mechanical harvesting of green beans may lead to discoloration of the broken ends of the bean pods, especially if there is a delay in processing them.
The aim of this study was to choose the appropriate operating mode of mechanical harvesting system for green bean production. The harvesting machine used in the study was a Ploeger BP 700 bean harvester. This machine is primarily intended for use in edible green bean harvest, however, its design allows it to be used in a variety of vegetable crops.
The harvest efficiency was found to vary from 51 to 83% and was dependent on plant spacing and height, which affected pods location on the plant.

Key words*: Phaseolus vulgaris L., green bean pods, combine harvester, quality, losses.*

1. INTRODUCTION

The agriculture have a major role in the Serbian economy accounting for 18% of GDP and 23% of exports in 2009 [6].

Production area under vegetables in Serbia amounts to about 270,000 ha, which represents 9 % of the total arable land [15].

Common bean (*Phaseolus vulgaris,* L.) is known under different names (Green bean, French bean, kidney bean, snap bean, runner bean, string bean). It can be grown as a vegetable crop for fresh pods or as a pulse crop for dry seed.

Growing time of green beans over as double cropping sowing certainly brings to increasing efficiency of soil using and thus increase income. Green beans as double cropping sowing necessarily go along with irrigation. Intensive irrigation affects the increased leaching of nutrients and this should be taken into consideration in determining of the fertilization norm.

1.1. Green beans production

World production of green beans is performed on the surface of 1.5 million ha, with total output about 20 million tons.

On the top of producers countries are the China (615,000 ha), India (218,352 ha) and in Europe Turkey (65,652 ha). According to the production area of green beans, Serbia is the eight in the world [5].

Countries that are leading producers of green beans in the 2011th year are shown at Figure 1.

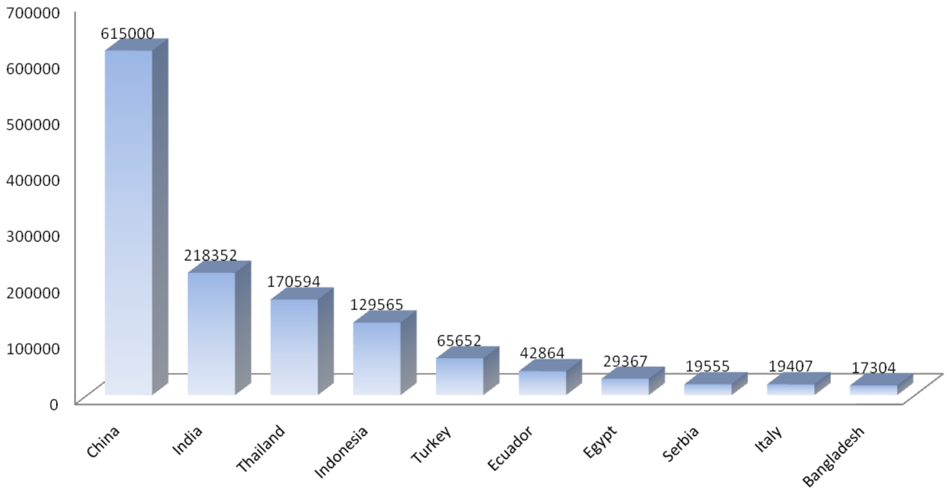

Figure 1. The green bean production area (ha) at the world in 2011th year

1.2. Green beans harvesting

In recent times, harvest mechanization research and development has focused on processed vegetables, whereas fresh market crops currently machine harvested are not represented, and include among others green beans [8].

The lacking research in recent times to develop viable alternatives for hand harvesting can be explained by the following things. Crops that are still hand harvested are represented minor vegetable crops that have relatively small contribution of production. This includes most small business enterprises. They cannot justify the expense of several machines to harvest multiple crops. Green beans are exceptions that can be machine-harvested profitability with simplified machines. The high research costs associated with the development of new harvesters cannot be justified given the limited economic return for such small markets [14].

Green beans as processing crops are harvested in a single phase, whereas crops for the fresh market are generally harvested over a three-week period.

1.3. Literature review of harvesting green beans

Mullins [10] seven snap bean cultivars were evaluated for yield and pod quality characteristics at different harvest maturities. Yield increased as harvest was delayed, but declined at the last harvest date. Pod clustering, broken pods, percentage of pod passing no. 5 sieve, length of seed in pods, and pod firmness increased as harvest was delayed.

Peruzzi [12] his field studies were carried out on the mechanical harvesting and grading of French beans. The mechanized system consisted of a single-row harvester, transporter and vibrating sorting table. Losses during the harvesting operation were 12-19 %.

Bajkin [1][2] gives the effects of mechanical green bean harvest, which includes testing of three types of self-propelled combines: FMC, Ploeger and Pixall. During working of the combine Pixall measured losses, depending on the speed of movement, of the 8.62-10.25 %, with the combine FMC of 13.92-21.25 % and 16.66-24.02 % of the combine Ploeger.

Glancey [7] is based on the harvesting characteristics of several different bean cultivars, a mechanical harvesting index for bush-type crops that relates the pod setting architecture of a cultivar to harvest loss was developed.

Bjelić [4] was studied snap bean yield in a field trial included: 1) multiple-pass pod harvest and 2) single-pass pod harvest (control). The effect of single-pass harvest on snap bean yield was decreasing pod yield. However, single-pass harvest (mechanical harvesting) is widely used on large snap bean production areas.

Rafaeli Neto [13] studies were conducted to analyze variables related to the losses in the mechanized common bean harvest and evaluate the spatial relations between land altitude, plant height, first legume insertion height, weed natural incidence, grain yield, natural harvest losses, harvest losses in the cut platform and total losses. The total average loss was 14%, with 2% losses due to natural causes, 6% due to the machine internal mechanisms and 6% due to the platform cut.

Nikolić [11] in his research has concluded that the average age of the combine to harvest green beans, in Republic of Serbia, is over 18 years old. In the year 2009. there were a total 10 green beans combine harvesters, including two Ploeger BP - 700.

Labor needs for bush bean production are approximately 15 to 20 hours per acre (1ac = 4046.9m^2) plus an additional 8 hours per acre if irrigated [9]. Machine harvested bush beans require from 3 to 20 hours per acre for harvesting, grading, and packing operations. Hand-harvested beans are labor-intensive and can require up to 300 hours per acre.

Estimated 2010 production costs per acre for irrigated, wholesale bush snap beans are as follows: Total costs are $5,265 and $1,699, for Hand-harvested and Machine-harvested, respectively.

2. MATERIAL AND METHODS

Self - propelled green beans combine harvester Ploeger BP - 700 was examined in this paper.

This harvester was studied at various working velocities. Losses and grain condition were monitored for each combination.

To obtain high quality product is necessary to identify the optimal harvest, taking into account that, within limits ranging from cultivar to cultivar, the ripening process increases the yield unitary but decreases the quality of the product.

The indication of the time of harvesting remains, therefore, a prerogative of the agricultural technician that follows the cultivation. In addition, to follow systematically the culture, one must know the characteristics of each cultivar to determine the optimal time to reconcile the needs of producers and those of the industry.

2.1. Technological characteristics of the researched green beans harvester

The self-propelled combine for harvesting green beans is object of our research.

The figure 1 shows the researched green beans harvester Ploeger BP - 700, and in Table 3 is shown his basic technical characteristics.

Figure 1. View of researched green beans harvesters at experimental plot

Table 3 Basic technical characteristics of researched green beans harvester

Characteristics	**Ploeger BP - 700**
Header width (mm)	3000
Weights (kg)	10500
Engine power (kW)	113
Hopper capacity (kg)	2300

The total working quality of the harvesters was evaluated by sampling green beans pods from the storage bin.

Test runs for each speed combination were repeated at twice in a field resulting in loss for each of the loss categories at each combination of speeds.

2.2. Location of the experiment

This exploring was performed in the August month 2009. Field experiment was located on a plot, 45^{o} $12^{'}$ $25^{'}$ N and 20^{o} $15^{'}$ $05^{''}$ E, 83 m height above sea level, the chernozem soil type, at enterprise "Titel Agro" d.o.o. in the area of town Titel, in Serbian province of Vojvodina.

On the researched plots was sown variety of green beans Unidor.

Before the start of the harvesting samples were taken from 1 m^2, diagonally in five samples, at the plot to determine the total yield.

2.3. Description of green beans production

UNIDOR (Royal Sluis) [3] **-** short stem variety with yellow pods. The plants grow upright, and the pods are formed very concentrated and high on the plant (100% in the upper third of the plants), making it suitable for manual and mechanized harvesting. Pods are straight and intense yellow color. Low green beans at our country are grown as garden crop, but much larger areas are intended for industrial processing, where is harvested by combine harvester.

Green beans was grown following green peas as double cropping.

The plots for growing of green beans is harrowed and rolled, as soil preparation.

The distribution of the starting mineral fertilizer is done before plowing.

Optimal seeding rate is 360,000 plants/ha, average 100 kg/ha. Green beans were drilled in rows 50 cm apart.

Green beans sowing are scheduled over an eight-week period from June to July. Green beans sowing at the experiment were performed at beginning of the month June.

The sprayer was used for chemical treatment against broadleaf weeds, diseases and pests.

Irrigation was performed with irrigation device of type self-propelled irrigation sprayer. Green beans where irrigated in twelve cycles per 15-20 mm of water.

Harvesting is done with a single-phase self-propelled green beans combine harvester.

3. Results and discussion

Pods yields of harvested green beans was reached values 12.54 t/ha on the experimental plot.

Losses incurred in the harvesting of green beans were observed as pods rest on the stems and picked and broken pods on the ground.

Speed changes of combine did not affect the quality of harvested green beans pod and amounts of impurities in a bunker of combine.

Table 5 shows the average value of losses for the researched harvester Ploeger BP - 700 depending on different operating speeds of combine.

Increasing speed of the combine leads to an increase total losses of green beans pods.

Table 5. Average single loss of green beans harvester from the total losses

	Working velocity (km/h)	Grain yield (kg/ha)	Pods on the stems (%)	Pods on the ground (%)	Total losses (%)
Ploeger BP-700	0.8	12,540	5.96	8.35	14.31
Ploeger BP-700	1.2	12,540	11.16	9.56	20.72

With increasing speed, combine come to increase the number of pods that remain unpicked on bean stalk, 5.96 to 11.16 %.

The significant amount of researched harvester losses can be explained by the fact that the harvester Ploeger BP - 700 was manufactured 1987th year and there is definitely an obvious difference in the technological level of construction and level of reliability in exploitation in comparison to contemporary harvesters.

4. CONCLUSIONS

Research of working quality green beans harvester Ploeger BP - 700 was performed.

The harvest efficiency was found to vary from 51 to 83% and was dependent on plant spacing and height, which affected pods location on the plant.

Pods yields of green beans, is 12,540 kg/ha, and crop condition significantly affected to the working quality of the researched harvester.

In the work of combines, with the increase of operating speed, total losses of green beans grow, with values in the range 14.31 to 20.72 %.

This research brings to the conclusion that by increasing the speed of the harvester was coming to increasing the amount of total losses.

Constriction of the old machines for harvesting green beans showed many shortcomings in relation to modern harvesters, both in terms of efficiency and in terms of quality of work.

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Original scientific paper

FIRST EXPERIENCE ON IMPLEMENTATION OF GLOBALG.A.P. STANDARDS ON DAIRY FARMS IN SERBIA

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Abstract. *GlobalG.A.P. (Global Good Agriculture Practice) is a private, sector body that defines and sets voluntary standards for the certification of agricultural production processes around the globe. GlobalG.A.P. is managed by "FoodPLUS GmbH" from Cologne, Germany. The main purpose of GlobalG.A.P. is providing mechanisms for control of food safety, the environment, working conditions for workers and welfare of farm animals. It is a pre-farm-gate standard, which means that the certificate covers the process of the certified product from farm inputs and all the farming activities until the product leaves the farm. With the development of GlobalG.A.P. standards, the uniform standard of good agricultural practice are developed. As in other countries, also in Serbia, the application of this standard is not required by law, but its use is entirely voluntarily, since GlobalG.A.P. belongs to the group of so-called "Private standards". In order to assess the possibilities, advantages and disadvantages of the implementation and certification of GlobalG.A.P. standards on livestock farms, 8 pilot dairy farms were chosen and over the period of two years (2012-2013) the complete GlobalG.A.P. standards were applied (all 4 modules related to milk production). The paper discusses the most important aspects of the implementation of these standards on dairy farms as well as its advantages, but also the difficulties and obstacles that can lead to increased unattractiveness and lack of interest of farmers for its application.*

Key words: *Private standards, pre-farm-gate standards, dairy farms, environment, food safety.*

1. INTRODUCTION

The concept of the systematic control of safety in primary agricultural production, and therefore in livestock production, began to be more intensely applied only 15 years ago originally as an initiative of the "Euro-Retailer Produce Working Group" (EUREP). Launched as a collaboration of retail associations in the UK and similar associations in continental Europe, this initiative was a response to the growing interest, and therefore concern, of certain consumer groups and their associations for food safety, environmental production standards as well as working conditions in which primary agricultural production is performed. The aim of the initiative was to standardize and harmonize the standards for agricultural products, prescribed by various retailers' associations who, between themselves, are often very different.

With that intention EUREP began to harmonize numerous standards and procedures that were applied in agricultural production gradually creating the concept of good agricultural practices (Good Agricultural Practices). This resulted in a set of standards named EurepGAP (European Retailers Protocol for Good Agricultural Practice). The popularity and applicability of these standards influenced the fact that in the next 10 years this initiative was joined by a growing number of both agricultural producers and retailers, not only from Europe but from all over the world, so the term EurepGAP gradually began to introduce a certain amount of confusion. Therefore, in 2007 it was decided to change the name of EurepGAP to GLOBALG.A.P. and that is the name this system for safety control of agricultural production is known by even today.

GLOBALG.A.P. (Global Good Agriculture Practice) represents today a private, sectoral body that defines and sets voluntary standards for certification of agricultural production processes that are applied throughout the world. GLOBALG.A.P. is managed by "FoodPLUS GmbH", a non-profit limited liability company with headquarters in Cologne, Germany. Since 1997, i.e. from the beginning of the application of EurepGAP standards until today, over 90,000 agricultural entities have been certified in over 100 countries (until 2011, Serbia had over 300 certified companies / enterprises / households).

The main purpose of GLOBALG.A.P. is providing mechanisms for the control of food safety, environmental protection, working conditions on the farm and animal welfare, with the aim of increasing the safety of consumers in regards to the production of agricultural food products [3]. It should be stated that food safety, environmental protection, as well as health protection and animal welfare are the three main aspects that are very important for the general public, i.e. the consumers, because it is a common belief that the improvement of the conditions of growing animals automatically affects the improvement of previously mentioned aspects of livestock production [8]. With the development of GLOBALG.A.P. a uniform standard of good agricultural practice is practically developed, the so called Integrated Farm Assurance standard (the IFA standard), which is applicable to a variety of agricultural production systems and products worldwide. In general, these standards function as instruments of coordination of supply chains by standardizing product requirements over suppliers, who may cover many regions or countries [6].

What significantly differentiates GLOBALG.A.P. from other control mechanisms for food production safety in the long chain "from the fields to the dining table" is the fact that GLOBALG.A.P. is a private and exclusively pre-farm and farm standard. This is exactly what differentiates it from HACCP or ISO based standards [7]. This system encompasses the control and certification both of farm inputs necessary for a single production (e.g. cattle feed, veterinarian medication, use of pesticides, artificial manure, seeds etc.), as well as all the production processes on the farm itself, until a certain raw material or product (e.g. milk, fatlings, eggs, fruit, vegetables etc.) leaves the farm. In addition, GLOBALG.A.P. is a business oriented system (the so-called "business-to-business label") and is not directly visible to consumers, but is extremely important for the functionality of the whole chain which enables food production safety.

As in other countries, the application of GLOBALG.A.P. standards is also not legally binding in Serbia. Instead, its application is fully voluntary, considering the fact that it belongs to the group of so-called "private standards". Almost all certified farms in Serbia are involved in crop production, vegetable and fruit production. The initiative for the application and certification of GLOBALG.A.P. is mostly taken by wholesalers or the farmers themselves, who wish to further develop production or whose goal is to cooperate with some wholesaler or supermarket chain. However, in recent years, there has been an increasing interest in the application that GLOBALG.A.P. has in livestock production, and especially in intensive dairy production, since large dairies increasingly take this initiative [1, 2]. Bearing this in mind, the aim of this paper is to analyze the possibilities for the application of the GLOBALG.A.P. standard at dairy farms of various capacities, which are either business partners of large dairies or process the produced milk by themselves.

2. MATERIAL AND METHODS

Eight commercial farms with different capacities were selected for the purpose of analyzing the possibilities of implementing the GLOBALG.A.P. standard on the dairy farms, and their owners have agreed to participate in this research. Out of 8 farms involved in the research, cow's milk is produced on 7 farms, and they all belong to the family farm group, while the eighth farm produces goat's milk, and it belongs to the group of corporation farms, as all the milk is processed in the dairy which belongs to the same company.

The farms included in this analysis had different capacities, ranging from small family farms to large family and corporate farms. The number of heads of cattle on the farms ranged from 20 on the small family farm to over 200 heads on large family farms, and over 250 goats on the corporate farm. The full GLOBALG.A.P. standard was implemented on all the farms, including all the four modules foreseen for dairy production, i.e. farm module (All Farm Base Module, AF), livestock module (Livestock Base Module, LB), module for cattle and sheep, i.e. ruminants (Cattle and Sheep Scope, CS) and the dairy production module (Dairy Scope, DY) [5].

The audit concerning the achievement of the conditions involves the control of several parts, i.e. modules which include different aspects of work on the farm. The audit of every module includes checking the achievement of certain requirements (designated audit items) which have been classified as:

1. MAJOR requirements – have to be achieved in full (100% of requirement achievement),
2. MINOR requirements – at least 90%, and for fruit and vegetables, 95% of these requirements have to be achieved (the exact number of requirements that have to be achieved is calculated with a certain formula on the basis of the total number of requirements which are to be achieved),
3. RECOMMENDATION – it is preferable that they be achieved if feasible,
4. N/A (Non Applicable) – followed by an explanation of why the requirement does not apply.

Estimating the achievement of each separate requirement is based on the utilization of specific control sheets (called "check list"), while the preparation of compliance requirements is based on the written recommendations of GLOBALG.A.P. The achievement of each requirement is confirmed by specific documentation, which is hierarchically divided into guides, procedures, work instructions and forms (records).

The total implementation of this standard on the dairy farms requires the achievement of a total of 238 requirements, out of which 91 belong to the MINOR group, 117 to the MAJOR group, while 30 requirements are recommended.

Three internal audits were performed during the implementation of this standard for the purpose of determining the state of standard achievement, i.e. at the beginning of the implementation, at the half of the implementation process, and at the end of the implementation. The obtained data was processed with the methods of descriptive statistical analysis by using the statistical package "GenStat 14.2" (VSN International Ltd., 2011) [4].

3. RESULTS AND DISCUSSION

The key to the success of implementing GLOBALG.A.P. on one farm is for the farmers to accept the commitment that GLOBALG.A.P. documentation is to be duly and timely kept in accordance with the nature of the document and the changes occurring during production. The full implementation of GLOBALG.A.P. on one livestock farm takes up to a year, primarily dependent on the specific production and farming conditions. The number of the documents (instructions, procedures, work forms etc.) varies from farm to farm, as well as from production to production, and may amount to several dozens, and even over100 different documents for a single farm and one type of production.

Table 1 shows the percentage of achieved requirements in separate modules, out of the total requirement number on each farm.

Table 1 Percentage of the requirements achieved at final audit in relation to the total number of GlobalG.A.P requirements for dairy farms.

	Farm 1 – 270 goats	**Farm 2 – 210 cattle**	**Farm 3 – 190 cattle**	**Farm 4 – 21 cattle**	**Farm 5 – 64 cattle**	**Farm 6 – 230 cattle**	**Farm 7 – 185 cattle**	**Farm 8 – 67 cattle**
AF	57.35	54.41	63.24	48.53	58.82	50.00	57.35	48.53
LB	92.00	95.33	92.00	93.33	94.00	94.67	78.00	86.67
CS	96.77	100.00	100.00	100.00	96.77	100.00	100.00	100.00
DY	93.42	100.00	98.68	85.53	84.21	100.00	96.05	89.47
Overall	85.54	88.31	88.31	82.77	84.62	87.08	80.00	80.62

The control points in the farm module (AF) are common and can be applied to all agricultural producers who wish to secure a GLOBALG.A.P. Certificate, as it includes the general issues of great importance for all the works on an agricultural farm. The farm module includes the audit of the following requirements: history and management of the location, i.e. farm; keeping documentation and internal audits; protection, welfare and occupational health and safety; subcontractors (and visitors); waste management, pollutant management, reuse and recycling; environmental protection; claims and complaints; product withdrawal/recall; feed protection; farm's Global G.A.P. status; usage of logo; in the end, there is product traceability and separation. Table 1 shows that the least achievement of requirements was present in this very module, which is understandable if we take into consideration the nature of such requirements. The only farm which stands out with a slightly greater achievement of requirements from this module is FARM 3, which had previously had an implemented HACCP system. Moreover, this module contains requirements which cannot be designated “N/A”, but which still cannot be achieved by most farmers, such as the mandatory first-aid training or mandatory risk assessment on safety working conditions.

The livestock production module (LB) defines the fundamental principles of good agricultural practices which are applied to livestock production. Specific requirements are in compliance with the specificities related to various types of bred animals and production system types, and are defined in special parts of the standard, which relate to specific livestock production. The livestock production module includes the audit of the following requirements: farm location; health of employees and occupational safety; procurement and identification of animals and their traceability; cattle feed and water for animals; buildings where the animals are located, facilities and equipment; animal healthcare; medical tools; animal delivery and dispatch; as well as the procedure involving deceased animals. Table 1 shows that the achievement of this requirement group is considerably higher and this is probably present on all the commercial livestock production farms, i.e. the fact that the most difficult requirements to achieve will be the ones from the “Farm Module”, and the more specific the modules become for a certain type of production, the greater the percentage of their achievement.

The control points in the cattle and sheep module (CS) may be applied to all who are involved in raising cattle and sheep (the goat module has still not been developed, but is currently in the development phase, so the ruminant module is currently applied instead) and who want to obtain the certificate, as it includes all the crucial issues for all the production processes on cattle and sheep farms. The ruminant module includes the audit of the following requirements: animal identification and traceability; raising animals and young animals; cattle feed (bulky and concentrated); living space conditions and buildings; animal hygiene; as well as keeping animals. It can be noted that the achievement of the requirements from this module, regardless of the size of the farm, is almost total, which confirms the fact that it will be much easier to achieve the requirements which are tightly related to production than general farm conditions.

Finally, one more module is audited in dairy production (dairy production module) (DY) and it is applied only on the farms which are primarily involved in dairy production. This module includes the audit concerning the achievement of the following requirements: farm registration; cattle feed; building hygiene; healthcare of dairy cows; milking process; buildings and equipment for milking; (zoo)hygiene; cleaning chemicals and other chemical agents. Despite the slight variations that occur, the achievement of these requirements was also very high on all the analyzed farms.

4. CONCLUSIONS

The first experiences concerning the full implementation of the GLOBALG.A.P. standard on dairy farms in Serbia show that GLOBALG.A.P. generates the greatest interest on newer farms, which have more intensive production or which aim to significantly increase their production scope. Younger farmers and farmers who have been working with large dairies in recent years are well familiarized with good agricultural production requirements.

The most frequent issues which occur during the implementation of the GLOBALG.A.P. standard on dairy farms are the ones which occur when the achievement of a certain condition is mandatory according to GLOBALG.A.P. (designated as MAJOR requirements), while its achievement is not required pursuant to our legal regulations (e.g. mandatory first-aid training or performed risk analysis for family farms). In general, the greatest difficulties occur in the application of the most general standards which are common to all agricultural farms (farm module), while the application of standards related to the specific livestock production is much easier.

As far as the significance of GLOBALG.A.P. is concerned, the first question that is always posed is whether the application of this standard on a single farm impacts the price increase of this farm on the market. No, GLOBALG.A.P. does not contribute to greater prices of products, but it contributes to the great security of farmers on the market, i.e. their better market positions. Large dairies, slaughterhouses, wholesalers and supermarkets increasingly expect their suppliers to have some applied standard of good agricultural practice so that the farmers who possess this can achieve the placement of their products more easily.

Finally, it needs to be mentioned that the implementation of the GLOBALG.A.P. standard on dairy farms, as well as on other livestock farms, indisputably requires certain investments – both in terms of finance and time, as well as numerous adjustments in the manner of conducting business, farm management and production. However, with the application of this standard, the farmer gains the experience through a different approach to the work and production, as well as the possibility to estimate whether the realized production level on his farm is worthwhile. However, it must not be neglected that, apart from the investment and a significant adjustment, both in the manner of the work, and in the production system, the application of Global G.A.P. on livestock farms enables the farmer to have a considerably better and safer market position in the increasingly demanding and complex livestock production.

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Original scientific paper

RESOURCE EFFICIENCY IN AGRICULTURAL PRODUCTION–ENVIRONMENTAL IMPACT INDICATORS OF DAIRY FARMING

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Abstract. *The world's population and food consumption are increasing drastically while natural resources are decreasing. The development of indicator systems which describe the sustainability of food production requires more detailed knowledge on resource use at the farm scale. The importance of management strategies in agricultural farming and how the intensity of production may influence the energy intensity, the Global Warming Potential (GWP) and, the requirement of arable land will be discussed. The presentation demonstrates system modeling to examine interactions between crop and livestock procedures and between levels of different input factors and their effects on yields in order to determine agricultural resource use efficiency. A life cycle inventory analysis is done for feed supply and feeding in dairy farming. Different site conditions, milk performances and diet compositions are proofed within the system boundary from "cradle to farm-gate".*

Based on direct and indirect energy inputs the energy intensity in dairy farming is calculated, which is linked with carbon dioxide emissions. Methane emissions of enteric fermentation and of excrements are determined as well as the soil-borne nitrous dioxide emissions. The GWP is calculated for different milk performances and vary in a range of 1.01 (4,000 kg milk cow^{-1} year^{-1}) to 0.38 kg $CO_{2\text{-equi.}}$ kg^{-1} milk (12,000 kg milk cow^{-1} year^{-1}). The energy intensity varies from 2.14 to 1.83 MJ kg^{-1} milk, and the use of arable land from 1.71 m² to 1.09 m² kg^{-1} milk, respectively.

In conclusion it is to highlight that improvement in resource use (e.g. fossil energy, land) and the mitigation of GHG emissions are not always in agreement. The holistic view on the environmental impacts in agricultural production is highly recommended to enhance the sustainability of food production.

Key words (bold): *dairy farming, energy, GWP, land use, sustainability indicator*

1. INTRODUCTION

The agricultural economy and agricultural science have to deal with the challenge to ensure food quality and food security while the amount of the needed resources is decreasing. The population on earth is drastically increasing up to 9.5 billion humans in 2050 and the requirement of livestock products increases drastically until 2050 (Steinfeld et al. 2006). Furthermore the environmental impacts of climate change lead to uncertainties of the future development of agricultural production and therefore for the food supply worldwide. The understanding of the processes and the estimation of the resource use at the farm scale is essential to develop strategies to enhance the efficiency of resource use and to mitigate greenhouse gas emissions in the agricultural sector.

The fossil energy use was increasing during the past decades due to the intensification and mechanization of production technologies in the agricultural production. But the increase of yields is not to estimate as adequate to the increase of energy input in the procedures (Pimentel, 1973).

It is necessary to assess the different production methods in an all-embracing content to determine the effectiveness of greenhouse gas (GHG) mitigation methods. Del Prado et al. (2010) pointed out that single GHG mitigation methods may increase in some cases emissions of other forms of pollution.

The arrangement of agricultural production processes influences the emission of climate-relevant gases and is therefore conductive for the reduction of the anthropogenic climate change. The agricultural processes are important sources of atmospheric nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2).

The livestock sector is a major user of land resources, predominantly for fodder and the production of concentrate feed. The milk and meat production are growing faster than the pasture and feed crop areas (Gerber et al. 2010). For that reason a prospective growing of land requirements for food production is expected and the efficient use of the arable land is becoming more important.

Several approaches concerning energy efficiency and global warming potential (GWP) in agricultural production and dairy farming already exist. Most of the studies are mainly focused on the feeding system in dairy farming, which also consider calculations on plant production for feed-supply (Bockisch, 2000; Cederberg and Mattson, 2000; Thomassen et al., 2008; Flachowsky, 2009; Rotz et al., 2010). The results of these studies are not, or only partially, comparable, due to different system boundaries and assumptions.

Goal of this study is to discuss the sustainability of resource use in dairy farming. Exemplarily the sustainability indicators energy intensity, arable land use and the GWP are investigated in a comparable and holistic point of view. The investigation is done exemplarily for site conditions of North-East-Germany. The study is focused on recommendations for management decisions in feed supply and feeding strategies of dairy farming. The influence of varying milk performances of the dairy cows on the environmental impact of dairy farming will be a discussed management strategy.

2. MATERIAL AND METHODS

2.1. System boundary and data

The system boundary of this investigation is defined from “cradle to farm gate”. The influence of emerging GHG emissions, energy intensity and land use for feed-supply and feeding of the dairy diet is discussed for different milk yields. The functional unit of this calculation is related to the unit of milk produced. The milk is corrected for its energy content to a standard of 3.5% protein and 4.0% fat. The considered milk yields range from 4,000 kg milk to 12,000 kg milk. The calculations base on the breed of Holstein Friesian cows with a body mass of 650 kg and on a birth rate of one calf per cow in a year.

The study includes the energy inputs in dairy farming, which are assessed on the basis of direct energy input and indirect energy input. Direct energy is used in form of fuel oil, e.g. diesel fuel and electricity. The indirect energy includes the energy input for resources, manufacturing machines and technical equipment (e.g. fertilizer). The energy intensity expresses the relation between energy input and the mass of the produced product, e.g. feed-stuff and milk. Along with the energy intensity also the generation of direct and indirect GHG emissions is calculated. The calculations include the primary energy input and the generated emissions, which arise in connection with the production, use and disposal of an economic good. The defined system boundaries enclose the energy input and GHG emissions of the production of purchased materials like fertilizer, concentrate, and machines. The energy intensity and the generation of GHG emissions are estimated for the whole procedure of plant production while the following procedure sections are enclosed: tillage, seeding, fertilization, plant protection, harvest, transportation, conservation, removal of the feed-stuffs from the storage and feeding.

Table 1 shows the energy input of the manufacture of the operating resources and the GWP.

Table 1. Basic data for indirect energy inputs and GHG emissions which arise by producing the operating facilities

Input		Unit	Energy equivalent	Unit	Global Warming Potential
	Diesel fuel	$MJ\ l^{-1}$	39.6§	$kg\ CO_2\ l^{-1}$	3.6*
	Machines	$MJ\ kg^{-1}$	108.0§	$kg\ CO_2 kg^{-1}$	0.4*
Mineral fertilizer	N(calcium ammonium nitrate)	$MJ\ kg^{-1}$	35.3§	$kg\ CO_2 kg^{-1}$	2.9*
	P_2O_5(super phosphate)	$MJ\ kg^{-1}$	15.8§	$kg\ CO_2 kg^{-1}$	1.2*
	K_2O	$MJ\ kg^{-1}$	9.3§	$kg\ CO_2 kg^{-1}$	1.1*
Pesticides	Herbicides	$MJ\ kg^{-1}$	288.0§	$kg\ CO_2 kg^{-1}$	11.0*
	Fungicides	$MJ\ kg^{-1}$	196.0§		
	Insecticides	$MJ\ kg^{-1}$	237.0§		
Seeds	Maize	$MJ\ kg^{-1}$	3.0	$g\ CO_2 kg^{-1}$	1.8
	Triticale	$MJ\ kg^{-1}$	3.0	$g\ CO_2 kg^{-1}$	5.6

§Hülsbergen et al., 2001 *GEMIS, 2006

The energy intensity and the included losses of the on-farm feed-supply is calculated by using the software REPRO (Hülsbergen et al., 2001), which is based on specific data from Germany.

To show the influence of changing management practices and site conditions in plant production on the energy intensity and GWP in dairy farming, different feed production processes are compared. The main factors on which derive the strongest impacts on yield formation are site conditions (soil), climate (location), water regime, type of vegetation, intensity of use and nutrient supply (N, P, K) (Käding et al., 2005). Four different yield formations are distinguished and designated as quality group 1-4 (Kraatz, 2012). Whereas quality group 1 demonstrates the group with the highest yield, the best site conditions and the highest input of fertilizer (table 4).

Table 2 shows the basic data for the indirect energy input and the generated GHG emissions of the production of concentrate.

Table 2. Indirect energy input and GHG emissions for the supply of concentrate feed

Feed-stuff	Energy input MJ kg^{-1}	$CO_{2\text{-equivalent}}$ kg CO_2 kg^{-1}
Triticale	2.64°	0.28§
Soybean meal	4.25*	0.39*
Rapeseed meal	5.26*	0.39*
Concentrate	3.58*	0.34§
Pressed pulps	3.89*	0.01*

§own calculations *GEMIS, 2006 °Kraatz, 2012

The GWP is regarded to assess the contribution of the gases carbon dioxide (CO_2), methane (CH_4) and nitrious dioxide (N_2O) to the greenhouse effect. The reference substance for global warming is CO_2, and the impact factors thus express the substances potential impacts as grams of CO_2-equivalent per gram of substance (Wenzel et al. 1997). For CH4 an impact factor of 25 (Forster et al., 2007) is used. The impact factor for N_2O is 310 (IPCC, 2006). The N_2O emissions from the soil are calculated according to IPCC (2006) with 1.25% of the Nitrogen input.

Methane emissions from enteric fermentation of the ruminants and the emissions from the manure management at the farm are calculated. Methane emissions from animal enteric fermentation are predicted using the empirical equation 1. Here the CH_4 emissions are related to the share of the forage on the animal dry matter intake of the dairy cows (Ellis et al., 2007).

$$CH_4\ (MJ/d) = 8.56 + 0.139 \times \text{forage}\ (\%) \qquad (1)$$

The methane losses from excreta are calculated according to equation 2 (Dämmgen et al., 2006).

$$EF = \frac{GE \cdot \chi_{CH_4} \cdot \alpha}{\eta_{CH_4}} \qquad (2)$$

EF - Emission Factor (in kg CH_4 $animal^{-1}$ a^{-1})

GE - Gross energy intake (in MJ $animal^{-1}$ d^{-1})

α – time conversion (365 d a^{-1})

η_{CH4} – energy content of methane (55.65 MJ kg^{-1} CH_4)

χ_{CH4} – methane conversion rate (0.06 MJ MJ^{-1})

2.2. Diet composition

The diet compositions of lactating and dry cows were formulated to meet the nutritional requirements for maintenance and milk production of the animals.

Therefore the requirements of the dairy cows regarding a performance orientated feeding with the parameter net energy lactation (NEL) and usable crude protein (C.P.) and a balanced and ruminant appropriate feeding with the parameters fibre content (XF >18%), ruminant nitrogen balance (RNB $\geq$0) and dry matter intake (DMI) are considered (Kirchgeßner, 1997). It is assumed that the diets are fed as total mixed rations to the separate performance groups of the dairy cows. Diets are calculated for two performance groups of the lactating cows and two groups of dry cows for the summer and winter, respectively.

Table 3 gives an overview about the ingredients of the defined diets as well as the changing share of concentrate feed in the diets in dependence on increasing milk yields.

Table 3. Composition of the defined diets for the dairy cows

	Milk yield				
	4,000	6,000	8,000	10,000	12,000
Feed-stuff	% of the diet				
Roughage ∑	*78*	*74*	*69*	*62*	*57*
Maize silage	25	24	22	21	23
Grass silage	33	28	27	23	29
Pasture	19	21	19	17	4
Hay	1	1	1	1	1
Concentrate ∑	*22*	*26*	*31*	*38*	*43*
Triticale	7	5	7	5	5
Soybean meal	0	1	2	5	8
Rapeseed meal	1	4	4	7	7
Concentrate mixture	14	13	14	17	18
Pressed pulps	0	3	4	4	5

3. Results and Discussion

3.1. Energy intensity and global warming potential of feed-supply

The energy intensity and GHG emissions of feed-supply on farm is analyzed for maize silage, grass silage, pasture, hay, and trticale. The results are shown in table 4. The calcuations were done depending on different site conditions, here demonstrated in quality groups 1-4. The energy intensity varies in a range of 31% within in the quality groups of the separate feeds and the GHG emissions in a range of 43%, respectively.

Both, the energy intensity and the GHG emissions vary in a significantly higher range between the different feeds than the different quality groups. The production of Triticale requires the highest energy input per kg dry matter and causes the highest amount of generated GHG emissions. Multiple cuts and comparatively high losses by harvest cause higher energy inputs and higher GHG emissions per kg dry matter for the production of hay and grass silage, compared to maize silage and pasture. The lowest energy intensity and the lowest GHG emissions required for feed-supply is that of grazing on pasture.

Table 4 Nitrogen fertilizer use, yields, energy intensity and GHG emissions of the feed produced on-farm.

Feed-stuff	Quality group	Fertilizer (kg N ha^{-1})	Dry matter (DM) yield (t ha^{-1})	Energy intensity (MJ kg^{-1} DM)	GHG emissions (kg CO_{2-eq} kg^{-1} DM
Maize silage[a]	1	144	12	1.68[g]	0.16
	2	132	11	1.66[g]	0.16
	3	114	9.5	1.69[g]	0.16
	4	90	7.5	1.83[g]	0.17
Triticale	1	149	5.5	2.57[g]	0.28
	2	135	5	2.64[g]	0.28
	3	104	4	2.84[g]	0.29
	4	80	3	3.28[g]	0.32
Grass silage[b]	1[d]	141	9	2.37[g]	0.23
	2[e]	65	7	1.99[g]	0.17
	3[f]	30	5	1.84[g]	0.15
	4[f]	0	4	1.92[g]	0.11
Pasture	1	140	8	0.95[g]	0.14
	2	80	6	0.84[g]	0.12
	3	20	4	0.65[g]	0.06
	4	0	3	0.83[g]	0.06
Hay[c]	1[e]	140	9	2.14[g]	0.25
	2[f]	74	7	1.78[g]	0.19
	3[f]	50	5	2.03[g]	0.21
	4[f]	0	4	1.58[g]	0.13

[a] 15% losses (REPRO) [d] 4 cuts [g] Kraatz, 2012
[b] 20% losses (REPRO) [e] 3 cuts
[c] 20% losses (REPRO) [f] 2 cuts

3.2. Influence of the feeding strategy on the energy intensity in dairy farming

The feed-supply of the diets for the dairy cows causes increasing energy intensity per cow in a year with increasing milk yields (figure 1).

Whereas the energy intensity per cow is increasing with the increasing milk yields, the calculations show that the energy intensity per kg milk is mainly decreasing. The energy intensity of feed-supply decreases at milk yields of 4000-8000 kg milk cow^{-1} $year^{-1}$ by 18 %. This effect is less or contrary with milk yields of 10,000 kg milk cow^{-1} $year^{-1}$ and above. It reflects that the higher energy input of feed-supply is not endlessly compensated.

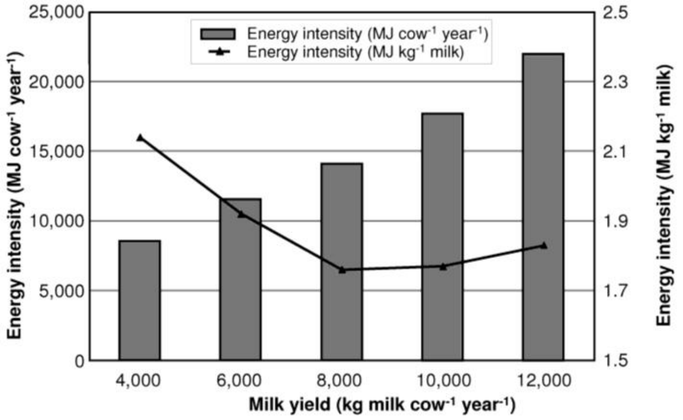

Fig. 1 Energy intensity of feed-supply in milk production dependent on varying milk yields

3.3. Influence of the feeding strategy on the GWP in dairy farming

The GWP of feed-supply and feeding in dairy farming are shown in Figure 2. The results show a 13% increase of the GWP per cow in a year with increasing milk yields from 4,000 to 12,000 kg cow^{-1} year^{-1} is about 13%. The investigations show a 62% decrease of the GWP is seen with increasing milk yields. This decrease is caused by the decreasing GHG emissions of the enteric fermentation which are connected with the increasing share of concentrate in the dairy diet with increasing milk performances of the dairy cows.

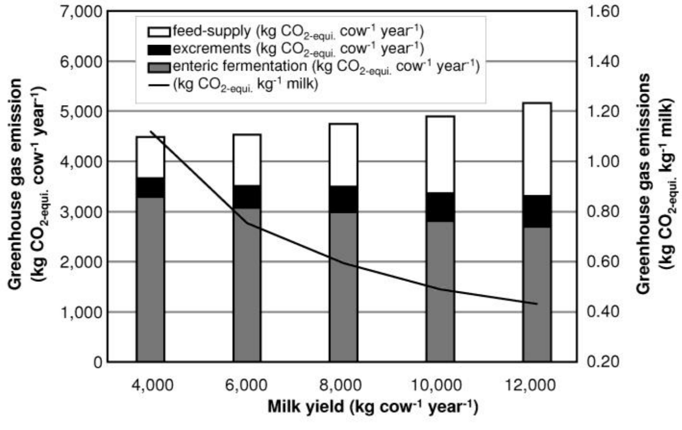

Fig. 2 GWP of feed-supply, enteric fermentation and excrements of dairy farming in dependence on varying milk yields

The main share on the GHG emissions of the feeding in dairy farming is caused by the enteric fermentation of the animals. In dependence on the milk yields from 4,000 kg cow^{-1} year^{-1} to 12,000 kg cow^{-1} year^{-1} the GHG emissions of enteric fermentation vary between 73% to 52% of the total GHG emissions demonstrated in figure 2. The feed-supply has the second highest share on the GWP. It is to highlight that the relations of the GHG emissions of enteric fermentation and of feed-supply vary with increasing milk yields. The investigations show that with increasing milk yields the generated GHG emissions from feed-supply, which are caused by the use of fossil energy, are rising up from 18% to 36% (figure 2). Main reason for this increase is the higher amount of concentrate in the diets. It is shown that the reducing effect on the GHG emissions from enteric fermentation by using concentrates in the diets is decreasing through the higher generation of GHG emission for its production.

The share of the excrements on the GHG emissions of feeding in dairy farming is slightly increasing by 3% with increasing milk yields from 4,000 to 12,000 kg cow^{-1} year^{-1}.

3.4. Requirement of arable land in dependence on site conditions of feed-stuff production and varying diets

The land requirement is strongly dependent on the site conditions, management practices and the target yields. The investigation show a requirement of arable land for the feed-supply of a dairy diet to produce 8,000 kg milk cow^{-1} year^{-1} is about 53% higher if quality group 4 is used instead of quality group 1 (Figure 3).

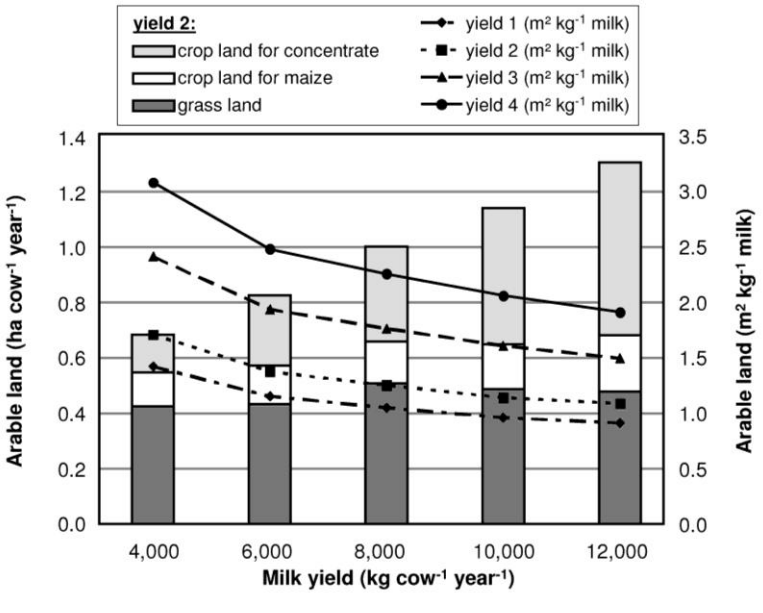

Fig. 3 Land requirement for feed-supply in dairy farming

The required area with conditions of quality group 2 for the feed-supply per cow in a year is shown in figure 3. The results show an increase of 52% for the land requirement per cow in a year with increasing milk yields from 4,000 kg to 12,000 kg.

The results show that the variation of the milk yields between 4,000 kg cow^{-1} $year^{-1}$ to 12,000 kg cow^{-1} $year^{-1}$ lead to a 36% decrease of the required arable land per kg milk.

The supply of feed for the dairy diet for milk yields of 4,000 kg cow^{-1} $year^{-1}$ and 12,000 kg cow^{-1} $year^{-1}$are provided by 62% from grass land and 63% of crop land, respectively. Feed-supply for the defined diet for a milk yield of 8,000 kg per cow in a year needs 50% grass land and 50% crop land. Effectively the requirement of crop land per kg milk increases slightly with the defined rising milk yields.

4. Conclusion

It is to conclude that the use of fossil energy, arable land and the mitigation of GHG emissions do not lead in all cases to same recommendations regarding sustainable production procedures in dairy farming. To give recommendations for GHG mitigation strategies and for improvement in resource use efficiency it is necessary to consider the interactions and impacts of the farm management strategies on the resources and the GWP within the comprehensive agricultural system. For plant production a similarity of increasing environmental effects is shown between the energy intensity and the GWP. The study shows that opportunities to reduce the energy intensity and the GWP go not necessarily along with the management strategies which lead to highest yields in plant production. Therefore it is to conclude that the environmental impact of the fertilizer used is not always compensated with increasing yields.

The investigation shows that the production of concentrate needs the highest energy intensity and generates the most GHG emissions compared to other feed-stuff. Pasture demonstrates the feed-stuff with the lowest energy input and also lowest GHG emissions. The main part on the energy input and the GWP of feed-supply takes the input of the operating resource fertilizer. Artificial fertilizer use causes 50% up to 75% of the energy intensity and of the GWP of feed-supply.

The present study verifies that different feeding strategies and milk yields have a strong impact on the required resources like fossil energy and arable land as well as on the GWP.

The increase of milk yields is a possible strategy to mitigate GHG emissions per kg of milk. But it is to point out that the mitigation of GHG emissions is not always shown as the solution with the lowest input of resources. The investigations show that the increase of the milk yield up to 8,000 kg cow^{-1} $year^{-1}$ is reducing all three considered aspects energy intensity, land use and GWP. For milk yields above 8,000 kg cow^{-1} $year^{-1}$ these effects are diminishing. The energy intensity is even rising up with milk yields higher than 8,000 kg cow^{-1} $year^{-1}$.

The increasing share of concentrate in the dairy diet which goes along with increasing milk yields leads to a reduction of the GHG emissions from enteric fermentation.

The requirement of land is decreasing with increasing milk yields which goes along with a change of the relation of the used land for the feed-supply. The area of required crop land is increasing with higher milk yields. It is to conclude that increasing milk yields support a lower requirement of arable land, but on the other hand it shows a disadvantage because the benefit of the ruminant animal to convert feed from grassland to food for human beings is given away.

Further investigations are necessary to gain more knowledge on the cross-linking and the sustainability of the agricultural production processes, e.g. on-going research is given on the implementation of the resource water.

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Scientific review paper

BENEFITS OF BIOSECURITY PLANS APPLICATION IN DAIRY FARM PRODUCTION

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Abstract: *Farm biosecurity is a concept which includes set of measures designed to protect a dairy farm production from the entry and spread of pests and diseases. It includes active approach of the farmer, being not only his responsibility, but also responsibility of every person visiting or working on the dairy farm. It is not easy to demonstrate specific and measurable benefits of proper and also effective biosecurity management, due to the highly complex nature of the system within which biosecurity practices operate. The aim of this review is to scrutinize the most important outcomes and benefits of biosecurity plan application for farmers, dairy industry and consumers.*
Certain measures require substantial investments, but comprehensive and consistently applied biosecurity plan is the most reliable and financially effective way to protect farm production. Countries experiencing a changing agricultural demographic, including dairy farm expansion, can benefit from documenting the implementation of on-farm biosecurity.

Key words: *biosecurity, benefits, dairy, farm*

1. INTRODUCTION

Farm biosecurity is a concept which includes set of measures, designed to protect a dairy farm production from the entry and spread of pests and diseases. It includes active approach of the farmer, being not only his responsibility, but also responsibility of every person visiting or working on the dairy farm [1].

The last occurrence of Foot-and-Mouth Disease (FMD) in the UK attracted huge media attention, not only because of the devastating images and destroying large number of cattle and pigs, but also because of the hard stroke to the national economy. Avoiding similar disasters must be a priority for all employees in livestock. Permanent and high awareness about the importance of preventing the introduction of infectious diseases in the herd must be subject to constant care and work on the creation, implementation and improvement plans of biosecurity measures [2].

Intensive dairy production is related to the high concentration of the cows in a relatively small space, which is reason that certain measures are necessary to preserve the health of the herd, prevent the introduction and spread of disease and maintaining certain production in the herd [3; 4].

Creation and implementation of biosecurity plans includes permanent work to create a satisfactory living environment for animals and their production, as well as to preserve it, especially in preventing the introduction and spread of infectious diseases and becomes more important as the dairy market is getting an international character [5].

2. FAILURES IN MAINTAINING BIOSECURITY

Maintaining a necessary level of health of the population is the most important aspect of satisfactory level of biosecurity and production success and welfare of dairy cattle, involves a series of biosecurity measures, and must be an integral part of the production technology, including good housing conditions, good and responsible treatment of animals and the use of prophylactic measures [3].

One of the most common problems is related to the basic understanding of biosecurity and what should be included in the case of certain farm. Expert opinions about the biggest threats to the safety of production on the farms might be very different from the real perception of problems in technology and possible penetration of infectious agents [6, 7]. Basically, the extend of applied biosecurity measures should be economically feasible [8], which is difficult to achieve at the beginning. Reviewing biosecurity on farms in the country during the transition period revealed numerous weaknesses in the now obsolete production methods that are still applied.

Biosecurity practices are focused on the prevention of importing diseases into a farm. The benefits to animal welfare, product quality, and farm profitability are well recognized and have been known for many years. Despite the obvious benefits of effective biosecurity programs, most dairy farms have few if any procedures in place to protect their herds. Far too many dairy producers view biosecurity as a mess of infectious agents, expensive tests, and time consuming animal handling schemes. In general, much of the emphasis on biosecurity has focused solely on the animal and the infectious agents. An important component of biosecurity, that has been far too often overlooked, is the importance and influence of the environment. Facilities and design can have a huge impact on the spread or prevention of disease [9], but neglect of the basic principles of environmental protection and animal hygiene threaten not only the production on farms, but also the health of the population.

Separation of facilities for the production in relation to potential sources of pathogens is an important biosecurity feature, especially when it comes to airborne infection. However, it should be kept in mind that the virus of FMD, Aujeszky's disease or enzootic pneumonia can be spread over long distances [10].

Also, it is almost impossible to achieve the required distance from dwellings, roads or manufacturing facilities in villages, where small stakeholders keep cows. One of the cardinal problems is the tolerant attitude of managers towards keeping farm by farm workers, own pigs, cattle or goats, which can be a source of infection for farm herd. Lack of green belt around the farm in areas dominated by east or northern wind contributes not only to cool the buildings and the creation of inadequate housing conditions as well, but may facilitate penetration of infectious agents in a circle of farm, and thus contribute to contamination of the objects and emergence of the infective diseases in animals [11].

Although in the introduction of newly acquired animals their health is crucial, namely serologic status and the accommodation in quarantine also might be problematic. Often these animals are kept within the farm itself, and thus the same staffs serve them and animals from the herd, which is not acceptable. It should be kept in mind that most animals from different age groups have special needs, often being of different geographical origin and health collected in a limited space. An important principle, the separation of age and production groups of animals, and staff that serves them, in biosecurity is often overlooked in everyday practice, especially in the case of hospitalized animals. In the implementation of biosecurity principles should be keep in mind that abandoned and criticized technological solutions, such as keeping the milking cows tied still apply on some farms, even though they cause discomfort, pain and distress of the animals. [3].

Even though some farms with knowledgeable staff takes care of a limited number of visits and not allowed to enter into or in the critical parts of the farm, the lack of serious and consistent mode of entry of vehicles and visitors in a farm circle and some parts of the farm is a serious problem, partly due to the unreliability of disinfection efficiency when entering the farm. However, a far greater problem is the complete disfunctionality of footbaths and checkpoints for disinfection and coating visitors at the entrance to the farm. Baths for the vehicles are poorly maintained, uncovered, and often lower than the surrounding terrain, which enables the collection of rainwater and surface water in them. Disinfection of shoes and hands is often a psychological barrier, while the dressing of often improvised, crossing paths with developments in their own and "clean" to wear to the farm. Showering before entering the farm is still considered "expensive and unnecessary luxury" and following "stand-down" period rule [12] is completely unknown.

In practice, very often some important elements of movement control are neglect, such as state of the fence, footbaths and procedures when entering the farm vehicles and foreign entities, even though all that is part of the farm design. Foot and wheel baths are regularly uncovered, exposed to the flowing of water, and the solution is not changed often enough [6].

When sanitation, as part of a technological process, is being applied properly and regularly to dairy farms, it will be successful. However, sometimes the cleaning and washing is not always carried out thoroughly, so disinfectants, which act only at the contact with the surface, might be ineffective. In addition, disinfection at the entrance, especially on cattle farms, is unsatisfactory. Price and efficiency are critical factors in the selection of disinfectants, and the less takes care of how to prepare resources for use and where his remains end up in nature.

The method and products for farms sanitation are presented in the papers [5, 13]. Occasional replacement of product is warranted when the sanitation using simple tools that do not destroy the entire microbial population with the consequent emergence of resistance remaining species, while the synergistic composite need not be changed for a long time, because they have a wide germicide spectrum, buffered with a longer residual effect [14], but at the same time must also take account of their corrosivity and biodegradability [11, 15].

On farms with the highest technological level certain procedures and protocols are being applied, which are primarily related to the control of movement of visitors and especially sanitation protocols, recommended by the sanitation preparation manufacturers in the form of standardized procedures [16]. Regarding the competence of professionals, it is noted that a number of animal husbandry and veterinary experts do not have a clear picture of the goals to be achieved by applying biosecurity plans, especially in the analysis of biosecurity indicators [17, 7].

3. BENEFITS OF BIOSECURITY PLANS APPLICATION

Having in mind size and production technology, objectives of each biosecurity plan will be always limited by financial, technical and staff capabilities [4]. Therefore, the definition of standards and assessments, existing level of development and implementation of biosecurity plans is in relation to its relative indicators and focuses on the farm possibilities. Special attention have to be paid to employees and the necessity of understanding the application of individual biosecurity measures and awareness of their overall impact on the current level of biosecurity (definition of biosecurity standards of production), as well as the current and future effectiveness of biosecurity measures [4].

The balance of all aspects of isolation could be far better when are respected and consistently applied the basic principles of the profession in the way of isolating and layout of individual objects, and also in any case of the introduction of newly acquired animals in the herd [18], functioning footbaths, technological ways of doing repetitive tasks such as feeding and milking [12], the proper use and disposal of used needles, syringes and other medical materials, and disposal of carcasses of dead animals, as well as procedures relating to sanitation facilities, resources and animals [11].

Demonstrating specific, measurable benefits of proper and effective biosecurity management is not easy, due to the highly complex nature of the system within which biosecurity practices operate. Anyway, the economic costs of infectious diseases are well established and clearly documented, and there is little doubt of the financial benefits in avoiding them [19].

Looking beyond the direct economics of disease reduction, the benefits of implementing on-farm biosecurity practices are significant. For dairy stakeholders, they include:

- improving animal health and welfare;
- keeping out new diseases;
- cutting the cost of disease prevention and treatment;
- reducing the use of medication, such as antibiotics, with an associated reduction in the risk of emergence of resistant pathogens;
- producing safe, wholesome, and high-quality products;
- increasing consumer and buyer confidence;
- protecting human health;
- minimizing the potential income losses;
- enhancing the value of the herd; and
- maintaining and accessing new markets for genetics.

A biosecurity plan provides overall benefits to the dairy industry in that it:

- decreases economic losses from some diseases that cannot be treated or controlled using vaccinations or other management strategies (e.g. mastitis, Johne's disease);
- helps to prevent the introduction of foreign diseases;
- controls the spread of infection from region to region and farm to farm;
- facilitates early recognition of emerging disease threats;
- prevents zoonoses;
- produces safe wholesome milk and dairy products; and
- maximizes genetic export markets by the prevention of disease.

Service providers, veal producers, feed businesses, and other business partners of dairy producers also benefit from farm biosecurity. Healthier day-to-day farm performance and the reduced risk of catastrophic disease events that severely impact farm afford customers more possibilities to protect their markets [19].

For example, dairy farms in Ireland are expanding in preparation for a new era of unrestricted milk production with the elimination of the European Union (EU) production quotas in 2015. Countries experiencing a changing agricultural demographic, including farm expansion, can benefit from documenting the implementation of on-farm biosecurity. Although less than 72% of farmers surveyed considered biosecurity to be important, 53% stated that a lack of information might prevent them from improving their biosecurity. Logistic regression highlighted regional, age, and farm-size related differences in biosecurity practices and opinions towards its implementation. Farmers in the most dairy cattle dense region were three times more likely to quarantine purchased stock than were their equivalents in regions where dairy production was less intense. Younger farmers in general were over twice as likely as middle-aged farmers to implement biosecurity guidelines. The owners of large enterprises were almost five times more likely to join a voluntary animal health scheme, and were over three times more likely to pay a premium price for health accredited animals than were those farming small holdings [20].

The putative benefits of undertaking biosecurity for disease prevention and/or control include improved production efficiency resulting in greater profits [21, 22], better animal welfare [23], improved immune responses to vaccines [24] and enhanced job satisfaction for producers, herd health professionals and other agricultural workers [25]. Nowadays, recommendations for a wide range of biosecurity practices exist for the major livestock production systems, either for general disease prevention, or to minimize specific infection risks, including zoonotic risks. A number of studies have recommended biosecurity practices for cattle production systems [24, 26, 27, 28].

Whilst many of these studies advise the use of preventive procedures, they do not often provide evidence on the efficacies or cost-effectiveness of engaging in such practices. The few studies that offer evidence of efficacy usually consider a single practice, such as disinfectant footbaths [29, 30], or look at the prevention of one disease only [31]. The considerable variation in recommendations between publications may lead to confusion amongst producers, resulting in them undertaking less appropriate practices. They may select practices that are ‘favored’, or easy to implement, which may not be the most effective for that holding [32, 33].

Benefits of biosecurity planning motivated many countries to establish Biosecurity Standards and/or Strategies for general purpose or for certain specific issue which has important impact to a national dairy production [34]. One of such documents is Tuberculosis (Tb) National Pest Management Strategy of New Zealand (1998). The main objective of the Tb National Pest Management Strategy is to reduce the numbers of Tb-infected cattle and deer herds to 0.2% annual period prevalence by 2012/13. Maintaining the 0.2% period prevalence for three years will allow New Zealand to claim official freedom from bovine Tb, eliminating the trade risk and providing a savings benefit of over $1 billion from reduced trade loss. These are certain activities that were anticipated in the Strategy:

- Development of a 15-year strategy that will test in some areas whether eradication is possible under New Zealand conditions, while containing and rolling back Tb in other areas and maintaining national incidence of Tb close to current levels (0.33% infected herds*)*, which should result in net industry benefit of $435 million plus trade loss benefit of up to $1.3 billion, with the dairy industry the greatest benefactor;
- Putting effective and tested systems in place to manage and mitigate significant biosecurity breaches, leading to protection against significant losses, e.g. New Zealand Treasury estimates the cumulative loss of earnings in national GDP from a FMD outbreak to the New Zealand economy could be $6 billion after one year and $10 billion after two years.

Sustainable dairying is about balancing profitability with environmental responsibility. This is the thinking guiding stakeholders' efforts in the work with farmers and industry partners to find environmental solutions that are practical and work on-farm, while reducing farmers' costs, and improving their efficiency and productivity. This system will lead to:

- Improvements in water quality in farming catchments, farmer freedom to operate and business security, effective partnerships between the dairy industry and regional councils, enabling negotiation of agreed catchment-scale target.
- Increasing the sustainability of dairy farming, through development of on-farm tools for diagnosis and management of environmental issues and deliver solutions that allow farmers to meet industry-agreed environmental best practice whilst maintaining productivity and profitability, and encouraging farmers to use the available tools and solutions, particularly those in priority catchments. That should maintain social licence to operate, improve public perception and increase profit from productivity. A reduction of just 5% in allowable farming is estimated to cost dairy farmers $440 million in direct income and the New Zealand economy up to five times this amount.
- Reducing greenhouse gas emissions through development of tools and technologies to reduce methane and nitrous oxide emissions from pastoral farming systems. That should reduce the need for New Zealand to buy carbon credits, as it is likely that farmers will bear this cost. Tools and new systems have potential savings for New Zealand of up to $300 million.
- Community impact is emphasized through promoted the image of the dairy industry, particularly around issues such as the environment and on-farm working conditions. Dairy industry is working to promote the benefits of the industry to the wider community, educates the public about dairy's environmental impact and shows them the work New Zealand dairy farmers are

doing to improve the sustainability of their farm business, enhancing public perception of dairy farming and attracting new people to the industry, promoting new science and technological breakthroughs and enhancing communication and networking.

- Animal welfare is the foundation of dairy farming. Healthy animals are productive animals. Also, being able to continue to assure consumers, regulators and citizens in general that dairy stakeholders look after animals well is important for ongoing farming business. Animal welfare applies not just on the farm, but also for off-farm activities such as transport of dairy cattle. Research and development helps to ensure that industry is doing things right by cows and that there is an international understanding of this, among consumers and regulators.
- Enhanced international competitiveness.

The objective of study of Hoe and Ruegg [35] was to characterize opinions and practices of Wisconsin dairy producers about biosecurity and animal wellbeing. Producers from large herds adopted more biosecurity practices than those from small herds, but biosecurity risks were common. The frequency of diagnostic testing and examination of purchased cattle increased with herd size. Producers minimized risks with which they were most familiar. Larger farmers had more knowledge of personal health risks related to zoonotic pathogens. Overall, most management practices were associated with herd size, but many beliefs regarding important dairy farm issues were consistent.

In making any biosecurity plan it must be started with identifying potential targets and key problems that may arise. In consultation with experts and in accordance with statutory requirements, the management of the farm should be decided that infectious agents are important for the development of biosecurity plan for the farm. Prevention and control of contagious diseases such as FMD are being planned and implemented at the state level. On the other hand, when it comes to the individual farm, infections and infestations caused by a large number of agents are a serious health problem that must be included in biosecurity plan based on risk assessment [2]. Risk assessment is a way to determine the presence, incidence and severity of disease on the farm. When risk areas or situations identified (then referred as the critical control points), should be made and implemented adequate control measures. Acceptable level of risk is determined by the possibility of the sale of all or certain products from the farm. It should be noted that the measures taken at critical control points is the most effective way of applying biosecurity plan [2].

Different sizes of production require different levels of protection, and hence control. This means that, as impossible and very expensive to protect all the elements of production in the same way, it should developed a system where the most secure biosecurity protection facilities, which are exposed to the greatest risk, are best protected [7].

Developing a farm biosecurity plan that includes the interaction of the animal, management and the facilities allows effective programs to be implemented and maintained [7].

Dividing the facilities, management activities and animals according to relative risk zones allows easier comprehension of biosecurity advantages or challenges. These categories can be considered as high, moderate, or low and/or colour-coded red, yellow, or green for ease of understanding. Employing a relative risk zone strategy for developing biosecurity plans has produced a much higher implementation of biosecurity procedures on dairy farms [9].

The purpose of introducing and consistent application of biosecurity standards on farms, shaped in biosecurity plans for each production unit in particular, have led to greater biological safety of food of animal origin, its quality and production volume, and above all, the protection of human and animal health, and must be known to everyone involved in livestock production [7]. In the context of production, biosecurity is a series of steps designed to herd management designed to prevent the introduction of infectious agents in the herd. The effort to preserve the health safety of food products of animal origin and their best quality is of great importance to the health and welfare of consumers. In addition, design and effective implementation of biosecurity measures have resulted in better animal health and increasing their productivity, and thus higher efficiency and profitability, and ultimately, the preservation of a healthy environment [8].

4. Conclusions

According all previously presented data about benefits of biosecurity plans application in dairy farm production, it might be concluded that:

– benefits for dairy stakeholders include improving animal health and welfare, keeping out new diseases, cutting the cost of disease prevention and treatment and reducing the use of medication, producing safe, and high-quality products and increasing consumer and buyer confidence, protecting human health, minimizing the potential income losses, enhancing the value of the herd;
– dairy industry benefits through decrease of economic losses from some diseases that cannot be treated or controlled using vaccinations or other management strategies, preventing and controlling the introduction of foreign diseases, negotiates more favourable global trade policies and maximizes genetic export markets by the prevention of disease;
– the effort to preserve the health safety of food products of animal origin and their best quality is of great importance to the health and welfare of consumers. Design and effective implementation of biosecurity measures have resulted in better animal health and increasing their productivity, and thus higher efficiency and profitability, and ultimately, the preservation of a healthy environment;
– prevention and control of contagious diseases such as FMD are being planned and implemented at the state level, while the individual farms solving health problems provides biosecurity plan based on risk assessment. It should be noted that the measures taken at critical control points are the most effective way of applying biosecurity plan.

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Original scientific paper

INFLUENCE OF THE CARP POND MODEL ON THE AMOUNT OF INVESTMENTS FOR ITS CONSTRUCTION

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Abstract. *Production of carp and related fish species in Serbia is carried out in fish ponds of different sizes and different technical and technological characteristics. In order to estimate in the most optimal way the amount and structure of investments in the selection process of different production models on the carp ponds, five organizational and economic models have been designed which reflect, in a representative way, the carp production situation in Serbia. Complete investment items have been defined for construction of those models, which need to be done before the production process begins. Structure of investments has been analyzed on the defined models, as well as the comparison of particular categories of investments between the different models. The analysis showed significant differences in the amount of investments and in the structure of investments depending on the applied model of the carp fish pond.*

Key words: *carp fish pond, organizational and economic models, investment*

1. INTRODUCTION

Carp ponds in Serbia are farms involved in carp and related fish species farming [5]. The total area of carp ponds in Serbia amounts to approx. 11.5 thousand hectares whereas there are differences between them in terms of their characteristics.

Carp ponds can be classified based on different hydrological, construction, production and technological properties [2, 4]. From the hydrological and construction properties point of view, ponds differ in terms of type of construction, construction site, size and manner of water supply. Based on their technological properties, ponds can differ according to the overall production process, farming system, fish farming mode and culture structure.

The initiation of any pond construction must be preceded by deciding on the mentioned production and technological as well as hydrological and construction properties of the future investment facility i.e. the carp pond. This decision influences the scope of construction works and the level of the technical equipment needed, i.e. the amount of investments for construction of the facility. In terms of the overall production process, there are semi-production systems and full production systems. The smallest difference between these two systems is reflected in the lack of the facility for keeping brood stock and spawning premises. Also, choice of the rearing system influences the size and depth of the pond, technical equipment necessary for intensive carp farming, in relation to those involved in semi intensive carp farming.

Considering the above mentioned the objective of the study was to analyze the investments needed for construction of different carp ponds, which best depicts the current situation in Serbia.

2. MATERIALS AND METHODS

During development of this study, data from several sources have been used, the first being the data from the Statistical Office of the Republic of Serbia related to total areas of carp ponds in Serbia, areas under exploitation, structure of the farming ponds as well as their technical equipment. Other source of data are the data from the carp ponds related to the necessary construction facilities, mechanization and other equipment used in the process of production. The third group of data are those from both domestic and foreign literature related research papers on pond establishment, pond construction, various technical characteristics etc.

Also, in the study appropriate methods have also been used for treatment of the collected data related to pond size, structure of fish production ponds and means of mechanization as well as a table presentation of the obtained results, The method for constructing organizational and economic models and adequate approach for determining the amount of funds for establishment of the investments have been used for economic analysis of the influence of the choice of hydro-construction and production and technological solutions on the amount of investment funds for establishment of fish ponds [1, 3, 6].

3. RESULTS AND DISCUSSION

Most carp ponds in Serbia are earthen ponds, in terms of type of construction. According to the site of construction they are fish ponds surrounded by dams. When it comes to manner of water supply, there are ponds with pumps for water supply and gravitational emptying. Ponds differ significantly with regard to their size (from < 5 ha to over 1000 ha), with about 50% of the total number of fish ponds being up to 50 ha in size. The second important indicator is that above 85% of areas under fish ponds belongs to fish ponds bigger than 150 ha [8].

With regard to production and technological properties, semi-systemic fish ponds established by supplying alevins of different fish species are important for the analysis. In terms of breeding systems, intensive systems are gaining more and more in importance, conventional semi-intensive (traditional) breeding systems of warm-water fish species as well as the higher level of semi intensive breeding. The higher level of semi intensive system is carried out in the same farming ponds as the conventional semi intensive system with the main difference being nutrition with complete feed. Carp breeding in intensive breeding systems is carried out in farming ponds of smaller sizes (1-5 ha), at a depth of 1.6 to 2.2 m [7] and deeper [2]. A possibility must be provided for continuous refreshment and aeration of water. Smaller area and a greater depth of pond compared to semi-intensive systems of breeding tend to increase hydro-construction activities. Technical equipment of intensive systems is far more demanding compared to semi intensive ones, primarily due to the need for water aeration systems.

Depending on the mode of fish farming, there is a two-year plant for carp farming closely linked to intensive breeding systems in Serbia and three-year plants present in the semi-intensive systems. According to the culture structure, there is pure monoculture (mostly seen in Serbia) in intensive systems and to some extent in semi-intensive systems and combined culture primarily seen in the semi-intensive systems.

Taking into account the previous analysis, and in order to be able to conduct a research of the majority of cases present in the carp breeding in Serbia, five organizational and economic models were defined in terms of hydro-construction and technological features. These are:

Model M1 – Carp production in intensive breeding systems in a fish pond of 10 ha useful area in a two-year plant using pure culture with average pond size of 2.5 ha

Model M2 – Carp production in intensive breeding system in a fish pond of 50 ha useful area in a two-year plant using pure culture, with average pond size of 5 ha;

Model M3 – Carp and related fish species production in semi-intensive breeding systems in a fish pond of 50 ha useful area in a three-year plant using pure and combined cultures, with ponds 2x 16 ha, 12 ha, 4 ha and nursery ponds 2 ha;

Model M4 – Carp and related fish species production in semi-intensive breeding systems in a fish pond of 150 ha useful area in a three-year plant using pure and combined culture, with ponds 2 x 50 ha, 23 ha, 15 ha, 10 ha and nursery ponds 2 ha;

Model M5 – Carp and related fish species production in semi intensive breeding systems in ponds of 500 ha useful area in a three-year plant using pure and combined culture, 3 X 110 ha, 2 X 65 ha, 2 X 12 ha, 11 ha and nursery ponds 5 ha.

After the models were defined, determination of the necessary funds was done for the supply, i.e. construction of the investment facility, which in carp farming consists of allocations for:

- analysis and projects but also other documentation prior to the start of construction,
- hydro-construction and construction activities,
- buildings, machines and devices,
- necessary tools, accessories and equipment.

Total funds to be allocated (amounts per ha and structure of expenditures) for the fish ponds and the defined models (M1 to M5) are given in Table 1.

Table 1. Investments needed for establishment of investment facilities

	M1		M2		M3		M4		M5	
	RSD	**%**	**RSD**	**%**	**RSD**	**%**	**RSD**	**%**	**RSD**	**%**
Documentation	1,035,000	9.6	1,975,000	5.0	1,725,000	6.5	3,675,000	5.7	6,375,000	5.0
Per hectare (RSD/ha)	103,500		39,500		34,500		24,500		12,750	
Hydro-construction facilities	8,219,000	76.0	31,367,000	79.5	20,730,000	77.7	50,795,000	79.2	101,080,000	78.8
Per hectare (RSD/ha)	821,900		627,340		414,600		338,633		202,160	
Buildings, machines and equipment	1,014,000	9.4	5,469,000	13.9	3,627,000	13.6	8,772,000	13.7	19,938,000	15.5
Per hectare (RSD/ha)	101,400		109,380		72,540		58,480		39,876	
Equipment	540,000	5.0	647,000	1.6	607,000	2.3	877,000	1.4	942,000	0.7
Per hectare (RSD/ha)	54,000		12,940		12,140		5,846.67		1,884	
Total (RSD)	**10,808,000**	**100.0**	**39,458,000**	**100.0**	**26,689,000**	**100.0**	**64,119,000**	**100.0**	**128,335,000**	**100.0**
Total per hectare (RSD/ha)	1,080,800		789,160		533,780		427,460		256,670	

Source: modified according to Čanak 2012 (parity 100 RSD = 1 €)

Total funds (in absolute amounts) for construction of carp ponds and procurement of the necessary machines and equipment tend to increase as the area increases. Substantially fewer funds (26.689.000 RSD, model M3) for the construction of semi-intensive carp ponds (50 ha in size) can also be noticed in comparison to the funds necessary for construction of an intensive fish pond on the same area (39.458.000 RSD, model M2).

The reason may primarily be in the scope of hydro-construction works (dams), due to higher number of smaller and deeper lakes near ponds with intensive production. The second reason is difference in the technical equipment, whereby intensive breeding ponds need more pumps and water aeration equipment.

Funds calculated per unit of useful pond area (RSD/ha) tend to decrease with the increase of the pond surface (an opposite effect was noted with the increase of the production intensity). The reason for this is primarily the increase of the pond surface on larger ponds which tends to decrease the necessary scope of hydro-construction works.

The structure of the funds indicates that the greatest percentage in all models is allocated for hydro-construction works, followed by construction facilities with machines and equipment. The great share of equipment related funds in the M1 Model compared with the rest of the models can be explained by the fact that part of the equipment necessary for functioning of even the smallest ponds (nets) does not change proportionally with pond size.

4. CONCLUSIONS

Carp species farming in Serbia is conducted in semi-intensive and intensive breeding systems in ponds of different sizes. In order to determine the necessary financial means for construction of ponds, five organizational and economic models (in terms of hydro-construction and technological features), of different sizes and breeding systems have been developed, which represent the existing condition in the best way.

The analysis has shown that increasing pond surface tended to increase the necessary funds (in absolute amounts). Actually, there was a significant decrease in the funds needed for establishment of one hectare fish pond with the increase of the total pond area. Compared with semi-intensive production, intensive fish production in ponds of identical sizes requires greater financial investments.

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Expert paper

TECHNICAL ASPECTS REGARDING THE CALCULATION OF AXLES OF ROAD TRANSPORT VEHICLES

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Abstract: *Mathematical models of mechanical structures, structural models are characterized by three main components: geometry, border conditions (bearing or ties with the outside environment for dynamic problems and initial conditions)) and the load (external actions on the mechanical system studied). The first component (geometry) is a idealized component of the reality – the shape of the body or the shape of bodies assemblies studied. This can be improved until the level desired by the analysts. The other two components (border conditions and load) are engineering assumptions. These components of the model, being engineering assumptions, must be either theoretically deduced and experimentally verified, either experimentally directly deduced by various of measurements. In general, when studying separate components of a whole assembly, these assumptions are difficult to formulate and thus, the overestimates lead to design of some massive structures, that generate high consumptions and reduced maneuverability. As easily, the underdimmensionnement may occur leading to more serious effects, malfunctions resulting with failures or major accidents. This article aims to tackle the issue of conditions (structure bearing) at the border of the structural model, suggesting solutions for the situation which, the components of a whole assembly are separately analyzed.*

Key words: *components, conditions, mathematical model, vehicles*

1. INTRODUCTION

Shafts and axles calculation constitutes usually a separate chapter in treaties of machine parts, but also, in some treaties for materials strength. The axles are defined, for example after [2], as being fixed machine parts with rotating or oscillating movements, designed to support other organs, which usually have rotation movement, without transmit twisting moments, their main request being the bending one.

The axles are framed within the broader category of shafts (improper called axes, after [3]), which is defined in [3] as being revolution solids bodies, with the maximum radius small, compared to their length.

The axis, as [3], is stressed primarily to bending and secondly to torsional, stretching and compression. Compared to most of the literature, [3] making vague references to the axes bearing: these are classified by the number of bearings (statically determined, when these have two bearings and statically indeterminate and when these have three or more bearings).

Also, the axes are classified by their mobility (fixed and rotary), or by the spindles position (bearing in console), etc. In [2] is given the axes classification in static determinants and static un-determinants, but does not give any definition of bearing.

[3] is very laconic in the definition of the bearing term, the external link that prevents some linear or rotational movements of a body. It defines the kinematical coupling through the mechanical system composed of two solid bodies in contact permanently directly, that allow the mutual relative motion and transmitting mechanical actions (forces and torques) between them.

In the literature, the structural modeling of axes has been often discussed, but with insufficient explanations often, regarding the issue of border conditions (ties or supports), [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15].

2. MATERIAL AND METHODS

The study uses as application material an agricultural trailer axle of 7.5 tons designed by INMA Bucharest. The axle has a central section by the filled square section with the side of 80 mm, 1590 mm long, soon afterwards, following two short sections at the ends of 27 mm, the circular transverse section with the diameter of 75 mm.

The remaining short sections at the ends do not interest the calculation. The material of which the axle is build is 1023 carbon steel (from the program materials library [4]), with the steel closest characteristics. The characteristics of the linear elastic material used in the analysis are: elastic moduluus, 210 Gpa, Poisson's ratio, 0.3, density, 7850 kg/m^3. To check the resistance are using the same steel features: tensile strength, 425 Mpa, yield strength, 360 Mpa, but they do not participate in the calculation analysis.

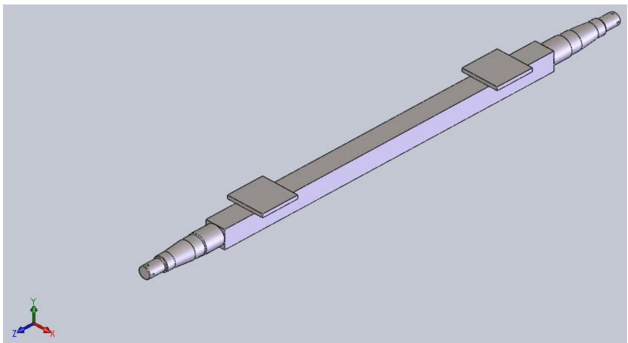


Fig. 1. Drawing provided by the designer of the agricultural trailer axle of 7.5 tons

Model with rigid bearing **-** *MR*

The first model is apparently normal for a beginner, namely the model of the axle bearing on the recessed rings in rigidly, ie by canceling all six freedom degrees at each node, which means restraint (away from the real model).

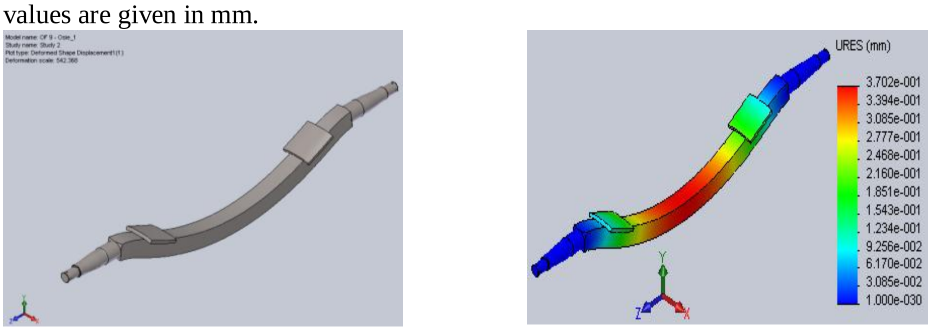
According to [4], the bearing applied through fixing the geometry of the cylindrical surfaces from the contact area of the axle with bearings, corresponds to *perfect restraint*.

ME **-** *elastic bearing model*

This model corresponds to an elastic bearing in the areas where the axle is bearing on the bearings, the elastic constant of the elastic bearings being 1080000000 (N / m) / m^2. This constant was chosen so that, by simulation to achieve a maximum relative resulting displacement and a maximum equivalent tension, close to those of the axle elementary theoretical model [1].

3. Results and discussion

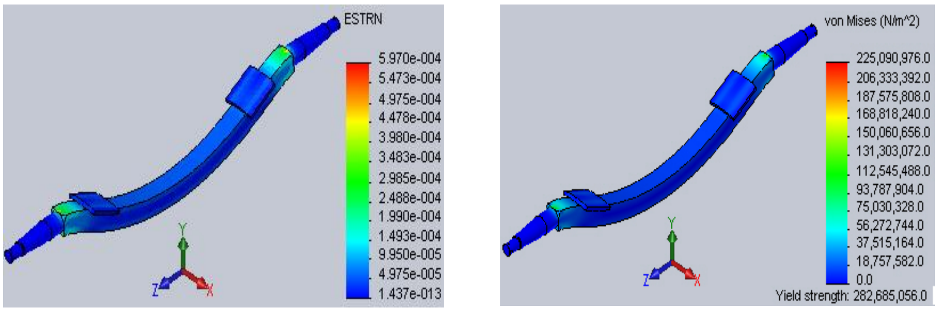
The main results of the two structural models of the axle are given in this chapter. In the case of *rigid bearing model*, the bloked areas do not leave their positions corresponding to undeformed configuration of the body. According to the structural analysis program used, [4], this bearing or connection is made by fixing the geometry from the cylindrical surface of the contact areas between axle and bearings. The state of the relative displacement resulted in the structure is represented in Fig. 2, a and b, the values are given in mm.



a) b)

Fig. 2. Deformed shape of the axle for the given conditions, a, respectively the state of the relative movement resulting in the axle model, in mm, b (rigid bearing model)

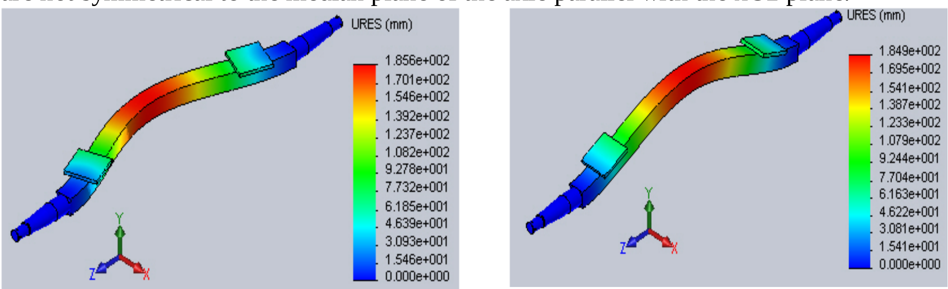
The total specific deformation state in the axle model is represented by the map from Fig. 3a, and the equivalent stress state in the built model of the axle is represented as a map on the deformed shape of the structure in Fig. 3, b. The values of the equivalent stress are given in Pa (N/m^2). The maximum stress is reached in the near of the bearings and has the value 225 Mpa. This value does not exceed the yield strength of the material. The maximum resultant relative displacement is localized in the middle of the axle, with the value de 0.37 mm (beam arrow less than 0.024%).



a b

Fig. 3. The state of total specific deformation in the axle model, a. The state of equivalent stress in the axle model în Pa (N/m^2), B (rigid bearing model).

The first two proper vibration frequencies of the axle and the deformed shapes at the maximum elongation are given in Fig. 4. The two modes of vibration are nearly identical, differing only in direction of deformation. The difference is caused by the plates which are not symmetrical to the median plane of the axle parallel with the xOz plane.

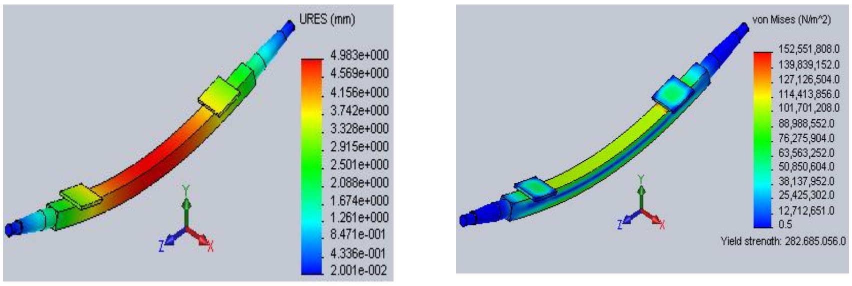


a b

Fig. 4. The relative displacement resulting in the deformed structure of the axle when this vibrates in the fundamental vibration mode (204.66 Hz), a, respectively, in the vibration mode corresponding to the second proper frequency (205.85 Hz), b (rigid bearing model)

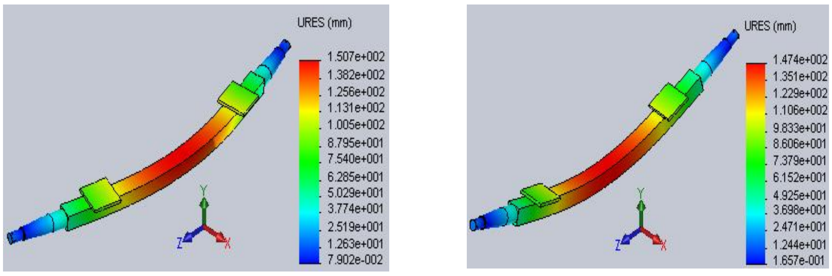
Below are given the results of the *elastic bearing model*. This kind of bearing envisages that, the axle is supported on the bearings and they are supported on the rim, which in turn are supported on the tire, that is an element with an elasticity higher than that of the metal. As a result, there is a redistribution of the stress in the weaker elements and simultaneously reducing the effort on the rigid elements.

The state of the relative resultant displacement in the axle, in case of elastic bearing and the loads used in case of rigid bearing are given as color map on the structure deformed shape in Fig. 5, a. The maximum resultant relative displacement is localized in the middle of the axle, with the value de 4.983 mm (beam arrow less than 0.32%). In Fig. 5, b is graphic represented as a color map the equivalent stress state in the structure on the deformed shape. In this case, the maximum value of the stress is near the axle load boards, with the value of 152.55 MPa. This value does not exceed the yield strength of the material and is much smaller than in the case of the rigid bearing.



a b

Fig. 5. The state of relative resultant displacement in the axle model, in mm, a, respectively, the equivalent stress state in the axle model in Pa (N/m2), b (elastic bearing model)



a b

Fig. 6. The relative resultant displacement in the axle deformed structure when it vibrates in the vibration fundamental mode (69,544 Hz), a, respectively, the relative resultant displacement in the axle deformed structure when this vibrates in the vibration second mode (69,893 Hz), b (elastic bearing model)

The deformed shape of the structure at vibration in the first and the second fundamental mode appears in Fig. 6, a, respectively, b. On the deformed shapes are given the color maps of the relative displacements resulting in the structure, in mm.

Note that spring mounted axle leads to increased deformation (relative resultant displacement) and lowering equivalent stress (with 32.2 %). Increasing the bearing elastic deformation when compared to the rigid case is relatively large, but fits very well within acceptable limits (beam arrow less than 1%).

Comparative summary of the results of the two models is given in Table 1for the rigid bearing mode, elastic bearing model and the reference model (with 32.2 %).

Table 1. Results synthesis of the structural models considered in this study

Model	**Relative displacement resulted**		**Equivalent tension resulted**		**The proper fundamental frequency, Hz**
	Maximum value, mm	**Location**	**Maximum value, MPa**	**Location**	
MR	0.370	The middle part of the axle	225.090	The extremities of the square section area of the axle	204,860
ME	4.983	The middle part of the axle	152.551	The vecinity of the limitrophe areas on that, the task is applied	69.544
Reference model	5.141	The middle part of the axle	135.571	The middle part of the axle	70.863

4. CONCLUSIONS

The reference model with that should be compared the results should be the experimental model. The ability of the structural model to reflect the reality would then be estimated by the difference between theoretical and experimental results. In this way it may choose a most faithful model of the real structure.

In the absence of some experiments, eg for a structure located in the design stage or maybe in the conceptual stage, the reference model used by the authors of this paper is the analytical theoretical model, the articulated bar at the ends and loaded symmetrically about the center.

The results of the reference model appear in Table 1, being calculated simply by analytical formulas and Saint Venant's formula. Terms of comparison are the maximum resultant relative displacement (and its location), the maximum equivalent tension (and its location) and, where is possible, their first propper frequencies.

A first conclusion of the study is that, the structure bearing mode influences decisive the effects produced at the same load on the structure: displacement, specific deformation, tension, spectrum of own frequencies.

A second conclusion shows that, the tension in the structure increases with its degree of rigidity, while maintaining the same load. At the same time, displacement in the structure decreases with increasing rigidity.

Through the degree of stiffening means the ratio between the number of freedom degrees canceled in the given case and the number of freedom degrees canceled in the reference situation for the same model and the same digitization. A precise measurement of the stiffening degree of a structure is not standardized.

The next conclusion refers the fact that, the elastic bearing gets closer by the reference model (model validated through good results obtained by means of it over a long time).

The elastic bearing used has adjusted characteristics, so that, the elastic bearing model to have a maximum relative displacement resulting as close to the reference model. To improve the model, the characteristics of this elastic bearing must be deducted from the characteristics of a natural suspension of the axle: rim and tire.

The superior model will also include submodels of support structures. Similarly, a better sizing will also be obtained by respecting more accurate compliance of the loads application on the structure (plates for force and even full representation of the chassis). It will not only get accurate information, but even more.

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Original scientific paper

TRACKS OR WHEELS – PERSPECTIVES AND ASPECTS IN AGRICULTURE

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Abstract. *The issue of tracked vehicles (tractors) or wheeled vehicles (tractors) for off-road operations has been a subject of debate for a long period of time. While a number of experimental studies in comparing the performances specific agriculture of tracked vehicles and of wheeled vehicles with those under selected operating environments have been performed, it appears that relatively little fundamental analysis on this subject has been published in the literature. This paper is aimed at evaluating the tractive performance of tracked and wheeled vehicles from the standpoint of the mechanics of vehicle–terrain interaction. The differences between a track and a tires in generating thrust are elucidated in agriculture. As the interaction between an off-road vehicle and unprepared terrain (soil) is very complex, to compare the performance of a wheeled vehicle with that of a tracked vehicle realistically.*

Investigations cover tracked tractor in harrowing and soil levelling coupled with an adequate implements, and wheeled tractors coupled with implements regarded harrowing and seedbed preparation.

Characteristics in a physical mechanical properties of non compacted soil (PMPS) like cone index, bulk density, total porosity, moment of torsion and shear stress, have been compared with compacted soil on passes under driving systems tracked or wheleed of tractors .

It is hoped that this papers will illustrate the fundamental factors that limit the traction of wheeled vehicles in comparison with that of tracked vehicles, hence contributing to a better understanding of the issue of tracks or wheels in conditions and perspectives in agriculture.

Keywords: *Tracks , Wheels, Conditions, Physical-Mechanical properties of soil (PMPS).*

1. INTRODUCTION

A comprehensive comparison of wheeled tractors vs. tracked tractors for a given mission and environment is complex in that it involves not only an evaluation of their performance, ride, handling and other characteristics, but also an assessment of their cost (including life-cycle cost), reliability, maintainability, etc.

A comprehensive evaluation will require a method of system analysis and is beyond the scope of this study. [3, 5, 13].

As adequate traction or tractive performance is a fundamental requirement of off-road vehicles, particularly for operation over weak terrain, this study will focus on the analysis of the basic factors that determine the traction of wheeled and tracked vehicles. Thus, it will illustrate the limitations of a wheeled tractors, from a traction perspective, in comparison with a tracked tractors.

2. Material and methods

1.1. Shearing characteristics of terrain

The thrust of a vehicle is developed by its running gear shearing the terrain surface. The shearing behaviour of the terrain is therefore one of the major factors determining the tractive performance of an off-road vehicle. In the following analysis, it is assumed that the shear stress–shear displacement relationship of the terrain can be represented by an exponential equation. It is described below and shown in Fig. 1. This type of relationship is often observed in mineral terrain in a natural environment [1], [2] and [3]

$$s=s_{max}(1-\exp(-j/K))=(c+p\tan\phi)(1-\exp(-j/K)), \quad (1)$$

where s is shear stress; s_{max} is the maximum shear stress or shear strength of the terrain, which is assumed to obey the Mohr–Coulomb criterion; j is shear displacement; K is the shear deformation parameter of the terrain, which determines the shape of the shear stress–shear displacement curve, as shown in Fig. 1; c and ϕ are the cohesion and angle of internal shearing resistance of the terrain; and p is the normal pressure.

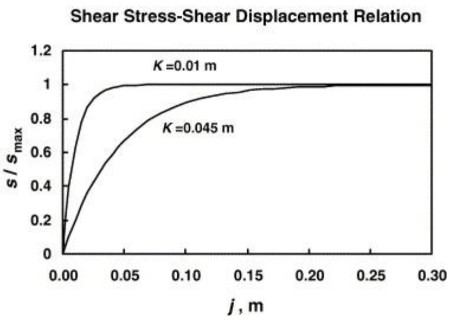

Fig. 1. Exponential shear curves with K = 0.01 and 0.045 m.

Fig. 1 shows two shear curves with K = 0.01 and 0.045 m, respectively. For most mineral terrain, the value of K falls in this range [2] and [3]. Additional information on the values of K for different types of terrain may be found in the literature [1], [2] and [3]. It can be seen from the figure that with K = 0.01 m, the shear stress increases more rapidly with the increase of shear displacement and reaches the maximum shear stress or shear strength at a much lower shear displacement than with K = 0.045 m. This indicates that with a higher value of K, higher shear displacement is required to reach the maximum shear stress.

In other words, when the shear displacement is below a specific level, the shear stress may be much lower with higher values of K, as shown in Fig. 1.

The value of the shear deformation parameter K, therefore, has a considerable influence on the development of shear stress under the vehicle running gear, hence the thrust (or gross traction) of the vehicle.

All the field measurements were made in the middle of the trails of tractors , on 100m lengths, at distances of 100 m, and covering areas of 1000 x 500 m. Measurement points 1, 2, 3, 4, 5 were distributed over these areas, at 20-m distances. During the investigation: soil density and the total soil porosity, shear stress, tangential moment, displacement were determined, with regard to the:

- number of passes (1 - 2), tractor and driving system types, - depth,
- moisture content, and different values of wheel or track slippage.

The torque (Nm) and the shear stresses (kPa) of untreaded (uncompacted) and treaded soil (compacted soil) after the 1 or 2 passes of tractor driving systems were determined by the shearing vanes method, the device for soil torsion EIJKELKAMP Self-Recording vane tester, Type IB. These parameters were measured at the depths of 10, 20 and 30 cm, in series of 5 repetitions.

- Numeric-analytic processing of all the obtained data was done with Excel.

1.2. Condition of a wheeled vehicle

If it is assumed that the tires of a wheeled vehicle have an essentially flat and rectangular contact patch with uniform normal pressure and the same contact length L_{ti}, and that the vehicle weight is uniformly distributed among the tires, then the total thrust (or gross traction) F_{ti} developed by n_{ti} tires of the vehicle at a given slip i can be expressed by [1], [2] and [3]

$$F_{ti}=n_{ti}[cb_{ti}L_{ti}+(W/n_{ti})\tan\phi](1-\exp(-iL_{ti}/K)), \qquad (2)$$

where b_{ti} is tire contact width and is assumed to be the same for all tires; W is the total weight of the vehicle; and i is the slip and is assumed to be the same for all tires. All other parameters in the equation are the same as those defined in Eq. (1).

As shown in Eq. (2), the thrust developed by a tire has two components: one is due to the cohesion of the terrain, which is related to the tire contact area, as described by the first term in the bracket of Eq. (2); the other is due to the friction of the terrain, which is determined by the normal load on the tire and the angle of internal shearing resistance of the terrain and is independent of tire contact area, as indicated by the second term in the bracket of Eq. (2).

It should be noted that the assumption that the tire has an essentially flat contact area is reasonable for a tire with low inflation pressures and operating on a relatively firm terrain. For a tire with high inflation pressures operating on a relatively soft terrain, this assumption may not be accurate, as the tire may behave like a rigid wheel [2] and [3].

2.3. Condition of a tracked vehicle

If it is assumed that the tracks on a tracked vehicle have an essentially flat and rectangular contact area with uniform normal pressure and the same contact length L_{tr}, and that the vehicle weight is uniformly distributed among the tracks, then the total thrust F_{tr} developed by a tracked vehicle with n_{tr} tracks at a given slip i can be expressed by [1], [2] and [3]:

$$F_{tr}=n_{tr}[cb_{tr}L_{tr}+(W/n_{tr})\tan\phi](1-\exp(-iL_{tr}/K)), \qquad (3)$$

where b_{tr} is track width and is assumed to be the same for all tracks on the vehicle. All other parameters in the equation are the same as those defined in Eq. (1) or (2).

It should be noted that the assumption that the track has an essentially flat contact area with terrain is reasonable for a rigid track with relatively long track pitch in relation to roadwheel spacing, commonly used in agricultural or industrial tracked vehicles. For a rubber belt track or a track with relatively short-track pitch in relation to roadwheel spacing, commonly used in military vehicles, this assumption may not be accurate, as the track in contact with the terrain usually has a curved shape and the normal pressure is not uniformly distributed [2], [3] and [4].

2.4. Comparison of the traction of a wheeled vehicle with that of a tracked vehicle

Fig. 2 shows a schematic of the four tires on one side of an 8 × 8 wheeled vehicle and that of a track on one side of a tracked vehicle. This will be used as an example for comparing the traction of a wheeled vehicle with that of a tracked vehicle. In the comparison, it is assumed that the wheelbase of the wheeled vehicle B is the same as the contact length L_{tr} of the tracked vehicle, as shown in Fig. 2. The spacing between the tires is assumed to be the same, thus providing the maximum total tire contact area for a given tire diameter and wheelbase, although in practice wheel spacing is not necessarily the same for an 8 × 8 wheeled agricultural tractors.

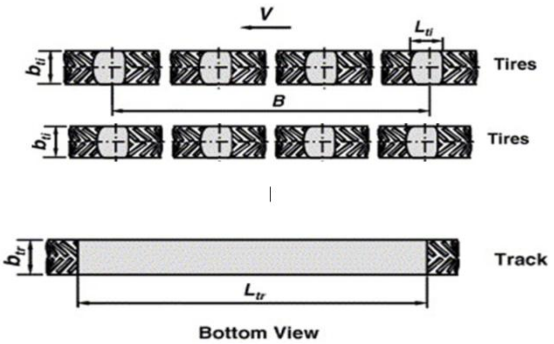

Fig. 2. Schematic of four tires on one side of an 8×8 wheeled tractor and of a track on one side of a comparable tracked vehicle.

Applying Eqs. (2) and (3) to the case shown in Fig. 2, the ratio of the thrust of a wheeled vehicle to that of a tracked vehicle, hereinafter called the thrust ratio, is expressed by

$$\frac{F_{ti}}{F_{tr}} = \frac{n_{ti}}{n_{tr}} \frac{\left[cb_{ti}L_{ti} + \left(\frac{W}{n_{ti}}\right)\tan\phi\right](1-\exp\left(-\frac{iL_{ti}}{K}\right))}{\left[cb_{tr}L_{tr} + \left(\frac{W}{n_{tr}}\right)\tan\phi\right](1-\exp\left(-\frac{iLtr}{K}\right))} \tag{4}$$

For the case shown in Fig. 2, it is assumed that $b_{ti} = b_{tr} = 0.38$ m, $B = L_{tr} = 3.3$ m, and tire outside diameter of 0.984 m (corresponding to that of a tire 325/85R16), and that vehicle weight W of 110.57 kN and slip i of 20% are the same for both the wheeled and tracked vehicle.

The lower thrust of the 8 × 8 wheeled vehicle, in comparison with the comparable tracked vehicle, is primarily due to the fact that with a much shorter contact length, the shear displacement at the rear of the contact patch of a tire will be much lower than that of a track at the same slip. This will limit the full development of shear stress on the tire contact patch in many cases, particularly when the value of K is high, as shown in Fig. 1. Since the thrust developed by a vehicle running gear is the integration of the shear stress over the contact area, with lower shear stress and lower contact area, the thrust developed by a wheeled vehicle will generally be lower than that developed by a comparable tracked vehicle. This can be further illustrated by Fig. 7, in which the development of shear stress under the tires of a wheeled vehicle is compared with that under a track. It should be noted, however, that with the same weight (or normal load) but having a lower total contact area, the average normal pressure under the tires of a wheeled vehicle will be higher than that under a comparable track.

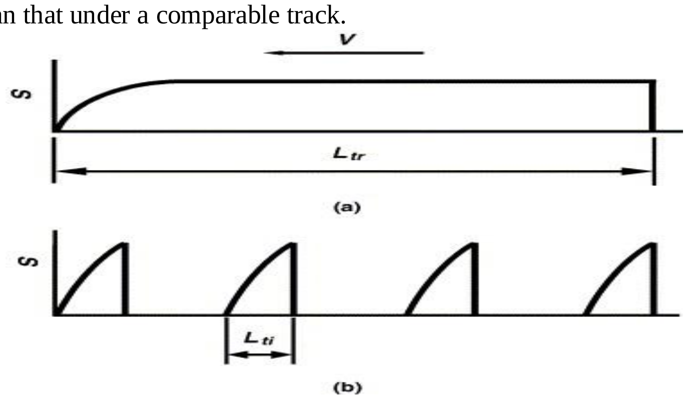

Fig. 3. Comparison of the idealized shear stress distribution under (a) a track and (b) tires.

In summary, based on the cases examined in this study, it can be said that the thrust (or gross traction) that can be developed by a wheeled vehicle is generally lower than that of a comparable tracked vehicle. This is primarily due to the fact that the tire contact length is much less than the track contact length of a comparable tracked vehicle.
As a result, the shear stress on the tire contact patch is usually less fully developed than that under a comparable track, other conditions being equal.

Among the vehicle design parameters, tire contact length, which is related to tire inflation pressure, has a noticeable effect on the thrust of a wheeled vehicle. Lowering tire inflation pressure, hence increasing tire contact length, would lead to improved traction of a wheeled vehicle, particularly on a soil with significant cohesion. Among the terrain parameters, the shear deformation parameter K has a significant influence on the development of thrust of a wheeled vehicle, because of its relatively short contact length. Other conditions being equal, on a firm sandy (or frictional) soil, the traction of a wheeled vehicle is less dependent on tire contact area. Therefore, the traction of a wheeled vehicle is closer to that of a comparable tracked vehicle on a firm sandy (or frictional) soil than on a clayey (or cohesive) soil.

The general analysis given above is useful in providing a physical insight into the development of traction of wheeled and tracked vehicles. It elucidates the differences between a tire and a track in generating thrust. It also identifies the vehicle and terrain parameters that would significantly affect the traction of both types of vehicle. It should be pointed out, however, that in the above analysis, the issue of wheels vs. tracks has been examined only from the thrust (or gross traction) standpoint.

The mobility of a vehicle on unprepared terrain is, however, determined by not only its thrust, but also its motion resistance. Furthermore, in the above general evaluation, a number of simplified assumptions have been made. These include the vehicle weight being uniformly distributed among the tires or the tracks, the contact area of the tire or the track being flat, the contact length being the same for all tires on a wheeled vehicle, etc. These simplifying assumptions in many cases are not necessarily realistic.

Furthermore, for a tire, the thrust is usually developed in part by rubber-terrain shearing and in part by the internal shearing of the terrain between lugs (grousers), and the relationship between tire inflation pressure and tire contact area (or contact length) has to be quantitatively defined.

All of these point to the need for the development of comprehensive computer simulation models, so that all these factors can be taken into account and the overall tractive performance of both the wheeled and the tracked vehicle can be realistically evaluated.

RESULTS AND DISCUSSION

The results of Analysis of Torque and Shear Stress in Tractor Running Gear shown in this work have been obtained through a investigation into the compaction soil of the Marsh of Soil , caused by different tractor driving systems [2,3,4], such as:

- wheel-drive tractor (8x8) IMT-5270 + disc tiller IMT-608.17.,
- track tractor TG-160 in aggregate with levelling machine,

The analysis of the results showed that the soil type was dark fertile marsh soil, and the soil class of heavy mechanical composition[4, 6, 20]: clay loam (the soil was composed of the following fractions: colloidal clay 17.86%, sand 31.99%, powder 50.15%.).

The analysis of the investigation results of the torque and shear stress of soil beneath tractor running gear covered the depth zone from 0 to 30 cm [7, 13, 9]. The torque and shear stress measurement results show certain differences in this parameter in the comparison: untreaded-treaded soil, depending on the type of the operation, number of repeated passes (one and two) and different wheel or track slippage values:

The disc tilling operation (IMT-5270 tractor 8x8 and TG-160 track tractor) has the characteristics of untreaded (uncompacted) soil and particular modes of machine tractor aggregate movement (Tab. 1).

Table 1. Moment of torque and shear stress of uncompacted Marsh soil

Numbers of repeated	(I)		(II)		(III)		(IV)		(V)		Average	
Dep. (cm)	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress
10	1.20	4.33	1.25	4.39	1.20	4.22	1.41	4.95	1.32	4.62	1.29	4.54
20	1.58	5.60	1.60	5.61	1.44	5.05	1.80	6.33	1.68	5.91	1.63	5.73
30	3.03	12.35	3.60	12.63	3.24	11.37	4.06	14.25	3.79	13.30	3.67	12.89

The disc tilling operation (IMT-5270 tractor 8x8) has the characteristics of an untreaded soil and particular modes of machine tractor aggregate movement (Tab. 2.). The change of the shear stress is: (9.08 to -15.14%) after the first pass of IMT-5270 tractor wheels, (11.62 to 15.86 %) after the second pass. The increase of tractor wheels slippage has considerable effect on the torque and shear stress. The analysis of the torque and shear stress mean values, with the biggest wheels slippage (s=25%) has shown abrupt changes in the torque: (3.40 to 4.79) after the first pass of the tractor wheels, (4.22 to 5.28) after the second pass. The change of the shear stress is: (11.93 to 16.79) after the first pass of tractor wheels, (14.82 to 18.51) after the second pass.

The disc tilling operation (TG-160 track tractor) has the characteristics of untreaded soil and particular modes of machine tractor aggregate movement (Tab.3). In the rear tracks trails, at the depths from 10 to 30 cm, certain changes in the torque and shear stress of the soil were recorded.

The analysis of the results (Tab. 3) has shown a different increase of the torque in the tracks trail (in comparison with the untreaded soil), with the smallest tractor tracks slippage s=3%, at the depths from 10 to 30 cm: (2.43 to 4.62) after the first pass of tractor tracks, and (2.44 to 4.79 Nm) after the second pass. At the same time the change of the shear stress is: (8.53 to 16.22 %) after the first pass of TG-160 tractor tracks, and (8.54 to -16.11 kPa) after the second pass. The analysis of the torque and shear stress mean values, with the biggest tracks slippage (s=10%) has shown the following changes in the torque: (2.42 to 4.79) after the first pass of the tractor tracks, and (3.25 to 5.16 Nm) after the second pass. Thus the change of the shear stress is: (8.50 to 1.79) after the first pass of tractor tracks, and (12.65 to 18.87 kPa) after the second pass. The tests of the torque and shear stress mean values have shown considerable differences between repeated passes.

Table 2. Moment of torque and shear stress of compacted Marsh soil for whells IMT-5270

Numbers of repeated	(I)		(II)		(III)		(IV)		(V)		Average	
Dep. (cm)	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress
Left wheels s=4 % First pass											IMT-5270	
10	2.20	8.50	2.50	8.77	2.40	8.43	2.82	9.89	2.63	9.24	2.59	9.08
20	-	-	3.10	10.8	2.79	9.79	3.50	12.2	3.26	11.4	3.16	11.1
30	-	-	4.00	14.0	3.60	12.6	4.51	15.8	4.21	14.7	4.08	14.3
Right wheels s=4 % First pass												
10	2.21	8.75	2.50	8.77	2.40	8.43	2.82	9.89	2.63	9.24	2.59	9.08
20	-	-	3.10	10.8	2.79	9.79	3.50	12.2	3.26	11.4	3.16	11.1
30	-	-	4.00	14.0	3.60	12.6	4.51	15.8	4.21	14.7	4.08	14.3
Left wheels s=25 % First pass												
10	3.30	11.2	3.20	11.2	3.41	11.9	3.25	11.4	3.15	11.0	3.25	11.4
20	-	-	3.95	13.8	4.19	14.6	4.21	14.7	3.88	13.6	4.06	14.2
30	-	-	4.50	15.7	4.86	17.0	4.79	16.8	4.43	15.5	4.64	16.3
Right wheels s=25 % First pass												
10	3.03	11.0	3.30	11.5	3.63	12.7	3.48	12.2	3.19	11.1	3.40	11.9
20	-	-	4.00	14.0	4.44	15.5	4.38	15.3	3.90	13.6	4.18	14.6
30	-	-	4.65	16.3	5.02	17.6	5.05	17.7	4.43	15.5	4.79	16.7
Left wheels s=4 % Second pass											IMT-5270	
10	3.00	10.9	3.15	11.0	3.03	10.6	3.55	12.4	3.32	11.6	3.26	11.4
20	-	-	3.35	11.7	3.02	10.5	3.78	13.2	3.53	12.3	3.42	11.9
30	-	-	4.10	14.3	3.69	12.9	4.62	16.2	4.32	15.1	4.18	14.6
Right wheels s=4 % Second pass												
10	3.05	10.9	3.20	11.2	3.04	10.6	3.61	12.6	3.40	11.9	3.31	11.6
20	-	-	3.55	12.4	3.25	11.4	4.00	14.0	3.75	13.1	3.64	12.7
30	-	-	4.40	15.4	4.09	14.3	4.96	17.4	4.63	16.2	4.52	15.8
Left wheels s=25 % Second pass												
10	3.90	13.9	4.00	14.0	4.26	14.9	4.06	14.2	3.94	13.8	4.07	14.2
20	-	-	4.50	15.7	4.77	16.7	4.79	16.8	4.42	15.5	4.62	16.2
30	-	-	5.10	17.8	5.51	19.3	5.43	19.0	5.02	17.6	5.26	18.4
Right wheels s=25 % Second pass												
10	4.5	14.8	4.10	14.3	4.51	15.8	4.33	15.1	3.96	13.9	4.22	14.8
20	-	-	4.80	16.8	5.32	18.6	5.26	18.4	4.68	16.4	5.01	17.6
30	-	-	5.10	17.8	5.61	19.6	5.53	19.4	4.86	17.0	5.28	18.5

Tab.3. Moment of torque and shear stress of compacted Marsh soil of track TG-160

	Numbers of repeated										**Average**	
	(I)		**(II)**		**(III)**		**(IV)**		**(V)**			
Dep. (cm)	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress	Mom of Torq.	Shear stress
Left track s=3% First pass											TG-160	
10	2.05	7.85	2.30	8.07	2.21	7.76	2.59	9.10	2.42	8.50	2.38	8.36
20	-	-	2.60	9.12	2.34	8.21	2.93	10.29	2.74	9.60	2.65	9.31
30	-	-	4.55	15.96	4.10	14.37	5.13	18.01	4.79	16.81	4.64	16.29
Right track s=3 % First pass												
10	2.40	8.80	2.35	8.25	2.23	7.83	2.65	9.30	2.49	8.75	2.43	8.53
20	-	-	2.60	9.12	2.38	8.36	2.93	10.29	2.75	9.65	2.67	9.36
30	-	-	4.50	15.79	4.18	14.66	5.08	17.81	4.74	16.62	4.62	16.22
Left track s=10 % First pass												
10	2.40	8.50	2.35	8.25	2.50	8.78	2.39	8.37	2.32	8.13	2.39	8.38
20	-	-	2.80	9.82	2.97	10.41	2.98	10.46	2.75	9.66	2.88	10.09
30	-	-	4.60	16.14	4.97	17.43	4.90	17.19	4.52	15.88	4.75	16.66
Right track s=10 % First pass												
10	2.50	8.90	2.35	8.25	2.59	9.07	2.48	8.70	2.27	7.97	2.42	8.50
20	-	-	2.80	9.82	3.11	10.90	3.07	10.76	2.73	9.58	2.93	10.26
30	-	-	4.65	16.32	5.02	17.62	5.05	17.70	4.43	15.54	4.79	16.79
Left track s=3 % Second pass											TG-160	
10	2.0	7.85	2.35	8.25	2.26	7.93	2.65	9.30	2.47	8.68	2.43	8.54
20	-	-	2.70	9.47	2.43	8.53	3.05	10.69	2.84	9.97	2.75	9.67
30	-	-	4.50	15.79	4.05	14.21	5.08	17.81	4.74	16.62	4.59	16.11
Right track s=3 % Second pass												
10	2.50	8.77	2.50	8.77	2.38	8.33	2.82	9.89	2.65	9.31	2.59	9.08
20	-	-	2.70	9.47	2.48	8.68	3.05	10.69	2.86	10.02	2.77	9.72
30	-	-	4.75	16.67	4.41	15.48	5.36	18.80	5.00	17.55	4.88	17.12
Left track s=10 % Second pass												
10	3.35	11.50	3.20	11.23	3.41	11.96	3.25	11.40	3.15	11.07	3.25	11.41
20	-	-	4.40	15.44	4.66	16.36	4.69	16.44	4.32	15.17	4.52	15.85
30	-	-	5.00	17.54	5.40	18.95	5.33	18.68	4.92	17.26	5.16	18.11
Right track s=10 % Second pass												
10	3.8	12.75	3.50	12.28	3.85	13.51	3.69	12.96	3.38	11.87	3.61	12.65
20	-	-	4.50	15.79	4.99	17.51	4.93	17.29	4.39	15.39	4.70	16.50
30	-	-	5.20	18.25	5.72	20.07	5.64	19.80	4.95	17.38	5.38	18.87

CONCLUSIONS

The problem of tractor driving systems effect on the compaction of marsh soils was studied in the region of the Marsh Soils of Makish (City, Zeleznik), near Belgrade, Serbia.

The objective of this investigation was to establish the resulting of changes and differences between untreaded (uncompacted) soils and those treaded by various class wheel 8x8 and track tractor driving systems.

The traction of a wheeled vehicle is closer to that of a comparable tracked vehicle on a frictional soil, such as sand, than on a cohesive soil, such as clay with medium or high moisture content. This is because on a frictional soil the traction is primarily dependent on normal load, whereas on a cohesive soil, it is primarily dependent on total contact area. As the total contact area of a tracked vehicle is usually much larger than that of a comparable wheeled vehicle, there is usually a more significant difference between the traction of a tracked vehicle and that of a wheeled vehicle on a cohesive soil.

The study methods applied required that the investigation of the changes due to the soil compaction caused by tractor driving systems be carried at the depth from 0 to 30 cm, and the measurements were taken at every 10cm interval to the depth of 30 cm.

This approach was accepted because of the statement made by many researchers who studied this problem, i.e. that more than 50% of all the changes occur after the first pass, and that the intensity of these changes drops sharply after repeated passes.

The obtained results of the soil compaction investigation enable us to conclude the following:

- The basic and additional soil preparation operations, depending on the test location, were carried out to the depth of 30 cm, with soil moisture content: 25.50 - 21.65%.
- Disc tilling (Tractor 8x8, IMT-5270), parameters recorded in rear wheel trails: soil density: 0.044 to 0.340 Mgm^{-3}; Total soil porosity reduced from 5.44 to 26.21%. Moment of torque: 2.59 to 4.62 Nm; shear stress: 13.22 to 26.05 kPa.
- Levelling (Tractor TG-160), parameters recorded in rear wheel trails: soil density: 0.024 to 0.173 Mgm^{-3}; Total soil porosity reduced from 2.61 to 26.71%; Moment of torque 2.43 to 5.16 Nm; shear stress: 8.53 to 118.87 kPa. Total soil porosity reduced from 2.61 to 26.71%;
- In order to protect soil (and physical-mechanical properties of soil) from damages due to its compaction caused by tractor and other vehicle driving systems, we must eliminate power intensive technologies from fields in crop production (heavy tractors with tires);
- Because all of them, tracks have very good perspectives in Agriculture in the future , and specially use rubber track tractors in many of agricultural production;

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Expert paper

MOBILE DEVICES AND ITS APPLICATION IN AGRICULTURE

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Abstract: *In recent years we have witnessed the incredible expansion of the smart mobile phones (smartphones) and tablets. Sales of such devices for several years is growing rapidly. These types of computers are slowly but surely pushing aside personal desktop at least as we knew in the past. With the development of a new generation of mobile devices has increased the number of mobile applications. Mobile applications are developed in all areas of interest, so the number of applications developed and applied in the field of agriculture. abstract*

Key words: *mobile applications in agriculture, mobile and tablet devices*

1. INTRODUCTION

ARM [1] is sort of microprocessor responsible for delivering all application in cell phones, as well as tablets and video consoles. **ARM** architecture which commonly known as **Advanced RISC Machine** and **ACRON RICON MACHINE** is architecture based on large scale of computer instructions with reduced command of instructions. That concept of microprocessor had influenced on better integrity, small dimensions, and faster responding time and with better energy efficiency. Parallel with hardware development, it had started development for program environment for **ARM** architecture with new applications for diversity of operational systems implemented in mobile devices. Those of well known operational systems in smart mobile devices are: **iOS** [2]**, Android** [2] **and Windows Phone** [2]**.**

Apple, **iOS** mobile operational system is made on multiple software layers (based on Unix platform), thus with all possible frames for programming and developing of its applications.

Goggle, **Android** is operational system based on software of Java applications. Open source operational system means that users have unlimited access to different applications, programs and any on-line content, for upgrading and developing.

On the other hand there is Windows Phone, operational system from Microsoft Company. There are several versions, and mean advantage is commodity and compatibility with base of other software products for Microsoft company.

2. APPLICATIONS FOR MOBILE DEVICES IN AGRICULTURAL MECHANIZATION

Programs for mobile devices in agriculture were developed and available for upgrading. Many programs were developed as application for necessary help in exploitation. We could trace them in two divisions. First group is group of programs and applications for collecting data in agriculture without necessity of gathering and processing data. Those are informational data, like: whether forecast e-catalogues, trade and market price of goods, etc…Second group find its purpose in gathering data necessary for planning, organizing and memorizing future, present and occurred business. Those are applications like assistance for maintenances and supplying tools.

In tractor industry and especially in maintenances service are very important applications of electronic tractor spare parts and auxiliary tools. There are also descriptions about basic technical characteristic of spare parts and ability of its service timing.

Application of Abilene Machine Parts Catalogue (**Abilene Machine Parts Catalog)** [3] is assistance tool for finding and selection of spare parts for tractors, harvesters and similar agricultural machinery. **Abilene Machine Parts Catalog** on Android platform is shown in figure 1.

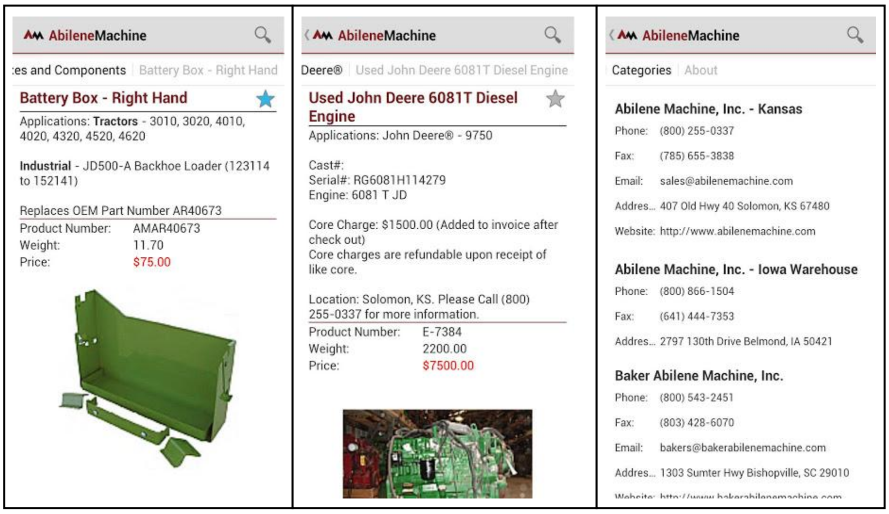

Fig. 1 Screen of application **Abilene Machine Parts**

Basic applications are:

- Electronic Base of new and available parts
- Detail information about spare parts and its price
- Screen of most parts needed for machinery
- List of favorites (e-mail, Linked etc...)
- Search of spare parts by serial number, name and description.
- Selected link, web, phone numbers, location and address of spare parts shop and service.
- Information about new products

Application **New Holland iBROCHURE** [4] is software product designed as interactive brochures as well video, text, and picturesque information about agricultural mechanizations, tractor, harvester, small tractor and industrial machines.

On figure 2 is shown display of application iBROCHURE (based on Android platform).

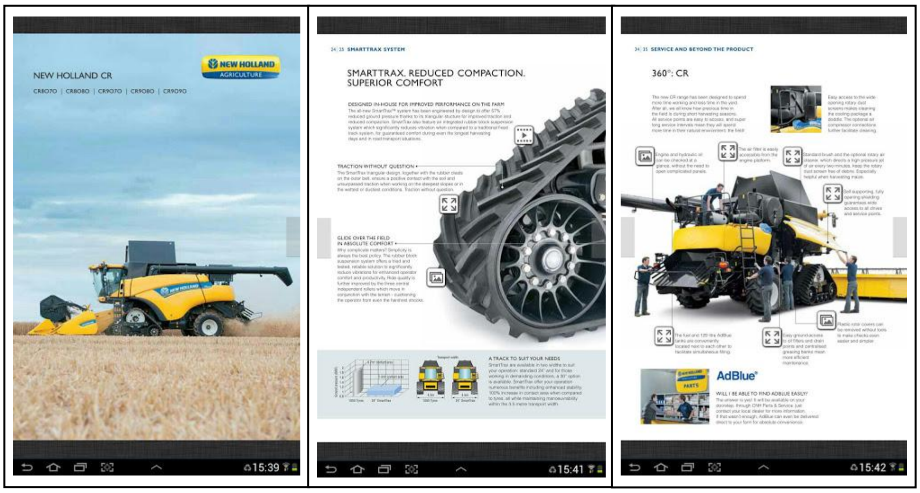

Fig. 2 Display of iBROCHURE

Application JDLink [5] is program for remote access and control of mechanization in field exploitation. During exploitation application provide operator check in critical working parameters in order to follow field data. JDLink has three options such as JDLink Express, JDLink Select and JDLink Ultimate. With those programs agricultural operator is able to follow:

- Productivity and effectiveness of tractor and agriculture mechanization
- Durability of agricultural machinery;
- Maintenances of working machinery;
- In use failures;

- Simplification of the maintenance of machines and tractors with valid documentation;
- Monitoring the number of field hours of Agricultural Machinery;
- Operator productivity;
- GPS location of mechanization with security information (for example anti-thief protocol) etc.;

On Figure 3 is given application display following field operations (Android platform).

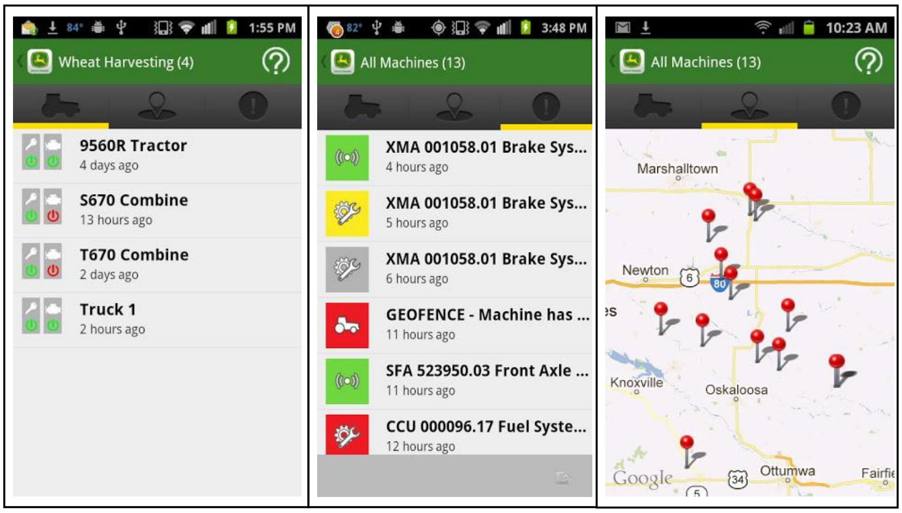

Figure 3. JDLink application is following certain field operations

Also, in addition to the above features, applications can be shown to contain information on trade fairs, exhibitions, and certain manufacturers of modern farm tractors and machinery.

3. CONCLUSION

Described mobile applications are only part of the program of interesting solutions that have emerged in the field of agriculture and related industries. These applications are not a substitute for more complex programs, designed for stronger PC hardware in the design, a larger planning, or more detailed data analysis and processing. Global networking leads to a huge expansion of mobile devices which will cause the development of a series of practical programs in this field. It is certain that the current and future software solutions allow the user between agricultural machinery, as well as manufacturers and service providers to develop more selective, economical and productive relationship..

This will certainly cause greater reliability and utilization of the machines, which will cause its further development, but also improve many other areas eg. ecology, safety, ergonomics, etc.

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Original scientific paper

OPTIMIZATION MODE OF THE ELECTRIC DRIVE PUMPS WITH THE DOUBLY-FED INDUCTION MOTOR

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Abstract. *This paper defines the opportunity to optimize the electric drive pumps with the wound rotor induction motor, which regulates the speed of a double feeding, with the stator from the power supply, and with the rotor through a semi-conductor converter, whose voltage and frequency can be independently regulated. Optimization is an action of the rotor voltage, at which, for a given frequency, the induction motor that drives the pumps operates with the rated currents of the stator and rotor, or with the stator and rotor currents whose ratio is equal to the ratio as at rated operation. Then the induction motor operates with minimal losses and maximum efficiency level, and then the demands of the semi-conductor converter are the smallest.*

Key words: *induction motor, double feeding, electric pump, semi-conductor converter, speed regulation, optimization of the rotor voltage.*

1. INTRODUCTION

Regulating of centrifugal pumps can be done in several ways depending on the specified requirements. The most efficient way is by changing motor rotation speed because in that case the pump has a high degree of efficiency in the wide interval of regulation [1].

Induction motors are widely used for centrifugal pumps drive. For a long time they have been used only as drive for constant rotation speed pumps, due to their inadequate regulating characteristics. However, lately, due to fast development of semi-conductor element especially the thyristors, which offer the new possibilities in induction motors speed regulation, they have been used with regulated electric motor pump drives as well, with are regulated by regulating the speed of induction motor drive [2].

One of the manners of regulating the speed of the induction motor with the wound rotor is by the double feeding from the stator side from the constant voltage and frequency network, and from the rotor side trough the semi-conductor converter, which enables independent regulation of frequency, amplitude and voltage phase introduced into rotor circuit (cycloconverters) [3]. Doubly-fed induction motor is very suitable, because of its characteristics for use as pump drive, as well as for other similar installations drive, such as fans, compressors etc. The main disadvantage of this speed regulation method is a relatively high price of the semi-conductor converter, but lately, thanks to wide rouge investigations and the results reached in the field of semi-conductor technique, this is becoming less of a problem.

Standard induction motor working conditions under double regime are considerably different from the conditions for which it has been designed, so that the use of classical semi-conductor converter, having rotor voltage regulated according to the following law:

$$u_2 = s \tag{1}$$

where u_2 and s are relative values of rotor voltage and slip, does not give satisfactory results, because it requires 10-20% load reductions as compared to its rated power, in order to prevent unpermitted heating [4].

Optimal efficiency of standard design induction motor, with speed regulated by double feeding, can be ensured by application of the appropriate law for regulating rotor voltage obtained from the semi-conductor converter, depending on the kind of the working machine driven by it. This paper defines voltage regulation method for doubly-fed induction motor, used for centrifugal pump supply, depending on motor rotation speed and load. The proposed method of regulating the rotor voltage refers to small and medium power motors.

2. MATERIAL AND METHODS

Stator and rotor currents of the doubly-fed induction motor depend on rotor voltage values. In order to reach optimal efficiency of a standard design induction motor under double feeding regime, in respect to useful power and heating, it is necessary to regulate rotor voltage in such a manner that the ratio between stator and rotor currents corresponds to the ratio for which it has been designed.

The rotor voltage regulation low for doubly-fed induction motor under synchronous work regime, which ensures the specified requirement it is possible to obtain from mathematical model in synchronous reference frame which rotates with synchronous speed ω_1 (stator circular frequency). In the chosen reference frame, the mathematical method can be represented by the following set of complex equations, [5, 6, and 7]:

$$\underline{U}_1 = R_1\underline{I}_1 + d\underline{\Psi}_1/dt + j\omega_1\underline{\Psi}_1 \tag{2}$$

$$\underline{U}_2 = R_2\underline{I}_2 + d\underline{\Psi}_2/dt + j(\omega_1 - \omega)\underline{\Psi}_2 \tag{3}$$

$$\underline{\Psi}_1 = L_s\underline{I}_1 + L_m\underline{I}_2 \tag{4}$$

$$\underline{\Psi}_2 = L_m\underline{I}_1 + L_r\underline{I}_2 \tag{5}$$

Using the differential operator p, the previous set of equations can be transformed to the following form:

$$\underline{u}_1 = r_1\underline{i}_1 + (p + j)\underline{\psi}_1 \tag{6}$$

$$\underline{u}_2 = r_2\underline{i}_2 + (p + js)\underline{\psi}_2 \tag{7}$$

$$\underline{\psi}_1 = x_1\underline{i}_1 + x_m\underline{i}_2 \tag{8}$$

$$\underline{\psi}_2 = x_m\underline{i}_1 + x_2\underline{i}_2 \tag{9}$$

considering the fact that the slip s is defined as:

$$s = f_2 / f_1 = (\omega_1 - \omega)/\omega \qquad (10)$$

For the stationary mode of operation ($p=0$) it becomes:

$$\underline{u}_1 = r_1 \underline{i}_1 + j\underline{\psi}_1 \qquad (11)$$

$$\underline{u}_2 = r_2 \underline{i}_2 + js\underline{\psi}_2 \qquad (12)$$

$$\underline{\psi}_1 = x_1 \underline{i}_1 + x_m \underline{i}_2 \qquad (13)$$

$$\underline{\psi}_2 = x_m \underline{i}_1 + x_2 \underline{i}_2 \qquad (14)$$

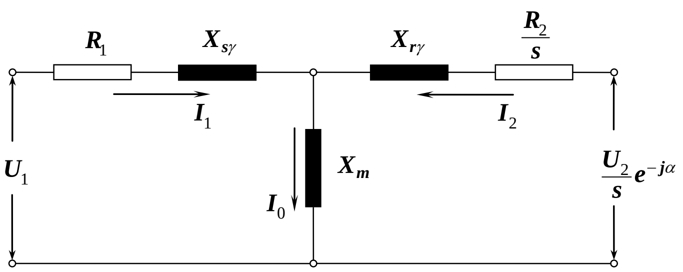

Fig. 1. Equivalent circuit of doubly-fed induction motor.

Presuming that the stator voltage vector coincides with the reference axis, complex expressions for the stator and rotor voltages become:

$$\underline{u}_1 = u_1 e^{j0^\circ} \qquad (15)$$

$$\underline{u}_2 = u_2 e^{-j\alpha} \qquad (16)$$

Starting from the equivalent circuit (Figure 1) and the vector diagram (Figure 2) of doubly-fed induction motor in synchronous mode of operation [4], the dependence of relative angle between rotor and stator voltage vectors α, and angle between rotor axis and stator voltage vector δ (load angle, according to the analogies with synchronous machine theory), is given by the relation:

$$\delta = \alpha - \beta \qquad (17)$$

where β is defined by: $\beta = arctg \dfrac{r_2 x_1 - s r_1 x_2}{r_1 r_2 - s(x_m^2 - x_1 x_2)}$.

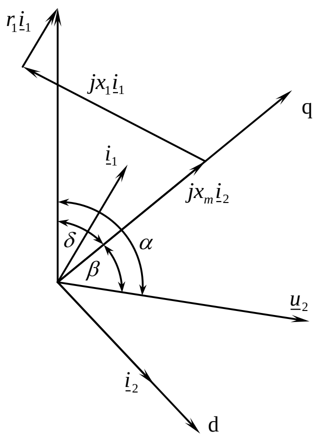

Fig. 2. Vector diagram of doubly-fed induction motor.

Solving the set of equations (11), (12), (13), (14), and taking into account the relations (15), (16), (17), expressions for all characteristic variables of doubly-fed induction motor in the given mode of operation are obtained.

The meanings of new variables introduced in the next expressions are:

$x_1 = x_{s\gamma} + x_m$, $x_2 = x_{r\gamma} + x_m$, $c_1 = x_m / x_1$, $c_2 = x_m / x_2$, $c_3 = 1 - c_1 c_2$, $x_{11} = c_3 x_1$, $x_{22} = c_3 x_2$, $k_1 = r_1 r_2 - s x_{11} x_2$, $k_2 = s r_1 x_2 + r_2 x_1$, $u = u_2 / u_1$, $a = r_1 r_2 + s x_1 x_2 - s x_m^2$, $b = s r_1 x_2 - r_2 x_1$.

Stator and rotor fluxes:

$$\underline{\psi}_1 = \frac{u_1}{k_1^2 + k_2^2}\{[x_1(r_2 k_1 + x_{22} s k_2) + u r_1 x_2 c_2 (k_1 \cos\alpha - k_2 \sin\alpha] + \quad (18)$$

$$+ j[x_1(x_{22} s k_1 - r_2 k_2) - u r_1 x_2 c_2 (k_2 \cos\alpha + k_1 \sin\alpha)]\}$$

$$\underline{\psi}_2 = \frac{u_1}{k_1^2 + k_2^2}\{\{r_2 x_1 c_1 k_1 + u x_2 [(r_1 k_1 + x_{11} k_2)\cos\alpha + (x_{11} k_1 - r_1 k_2)\sin\alpha]\} + \quad (19)$$

$$+ j\{-r_2 x_1 c_1 k_2 + u x_2 [(x_{11} k_1 - r_1 k_2)\cos\alpha - (r_1 k_1 + x_{11} k_2)\sin\alpha]\}\}$$

Stator and rotor currents have the active and reactive component:

$$\underline{i}_1 = i_{1a} + j i_{1r} \quad (20)$$

$$\underline{i}_2 = i_{2a} + j i_{2r} \quad (21)$$

$$\underline{i}_1 = \frac{u_1}{k_1^2 + k_2^2}\{[r_2 k_1 + s x_2 k_2 - u x_m (k_2 \cos\alpha + k_1 \sin\alpha)] + \quad (22)$$

$$+ j[s x_2 k_1 - r_2 k_2 - u x_m (k_1 \cos\alpha - k_2 \sin\alpha)]\}$$

$$\underline{i}_2 = \frac{u_1}{k_1^2 + k_2^2}\{\{-s x_m k_2 + u[(r_1 k_1 + x_1 k_2)\cos\alpha + (x_1 k_1 - r_1 k_2)\sin\alpha]\} + \quad (23)$$

$$+ j\{-s x_m k_1 + u[(x_1 k_1 - r_1 k_2)\cos\alpha - (r_1 k_1 + x_1 k_2)\sin\alpha]\}\}$$

The corresponding absolute values are:

$$i_1 = u_1 \sqrt{\frac{r_2^2 + s^2 x_2^2 + u^2 x_m^2 - 2ux_m(sx_2 \cos\alpha + r_2 \sin\alpha)}{k_1^2 + k_2^2}} \tag{24}$$

$$i_2 = u_1 \sqrt{\frac{s^2 x_m^2 + u^2(r_1^2 + x_1^2) - 2usx_m(x_1 \cos\alpha - r_1 \sin\alpha)}{k_1^2 + k_2^2}} \tag{25}$$

Electromagnetic torque:

$$m_{em} = m_1 + m_2 + m_3 \tag{26}$$

where m_1 and m_2 are asynchronous components, and m_3 is synchronous component of the electromagnetic torque.

$$m_{em} = \frac{u_1^2}{k_1^2 + k_2^2}(sr_2 x_m^2 - u^2 r_1 x_m^2 + ux_m \sqrt{a^2 + b^2} \cdot \sin\delta) \tag{27}$$

Rotor voltage, at which the motor works for given slip and rotation speed with nominal stator and rotor currents, can be obtained by solving the equations (24) and (25), where, in relative value, are i_1=1 and i_2=1. Because of the nature of the given equation they must be solved by using the interactive methods, by means of a computing machine. The law on rotor voltage regulation for given rotor rotation speed and slip, depending on load value changes, from idling to nominal, can also be obtained from general equations for stator and rotor currents, by substituting appropriate relative current values and by solving the equations in the a.m. manner.

The a.m. procedure had general character. In the case of electric motor pump drive it must be taken into consideration that the pump moment relation to the rotation speed is quadratic.

3. RESULTS AND DISCUSSION

The following is an illustrations of the character of rotor voltage regulation law for the induction motor whose speed is regulated by double feeding and which is used as drive for a specific centrifugal pump, in accordance with the specified requirements for a three-phase induction motor type ZPD (T) 112-M4 manufactured by "SEVER" Subotica, Serbia, having the following parameters:

P=3.7 kW, U=380 V, I_1*=7.9 A,* U_2*=220 V,* I_2*=10.4 A, n=1420 °/min,* $\cos\varphi$*=0.8, f=50 Hz,* η*=0.89,* r_1*=0.047,* r_2*=0.080,* x_1*=0.090,* x_2*=0.090,* x_m*=1.73.*

Rotor voltage calculation has been carried out in the a.m. manner, which is in accordance with set requirements for both cases and the results obtained have been presented in Tables 1 and 2.

Table 1. Relationship between rotor voltage and rotation speed with nominal stator and rotor current.

n [°/min]	1425	1350	1200	900	600	450	300
s	0.05	0.1	0.2	0.4	0.6	0.7	0.8
u_2 [$p \cdot u$]	0.066	0.078	0.14	0.32	0.48	0.59	0.70
U_2 [V]	14.5	17.2	30.8	70.4	105.6	129.8	154

As Table 1 shows, the value of rotor voltage given optimum efficiency of the doubly-fed induction motor used for pump drive, is lower than the value determined by the relation (1). That lowering is closely constant throughout the speed regulating interval, except in the range of small slips, where active resistance of rotor winding interfaces in relation to other kinds of resistance, which is especially pronounced in lower power motors [4].

Table 2. Relationship between rotor voltage and load current with speed n=1200 °/min.

I_2 [A]	6	7	8	9	10
I_1 [A]	4.55	5.31	6.08	6.83	7.6
U_2 [V]	37.6	36.1	34.9	33.2	31.5
u_2 [$p \cdot u$]	0.17	0.16	0.158	0.15	0.143

Calculations results given in Table 1 show that rotor voltage regulation, for obtained maximal efficiency, is also necessary for a given constant rotation speed, depending on the change of load, where it is necessary when the load increases, to decrease the rotor voltage.

Calculations carried out in the a.m. manner for a number of induction motors of different power show similar results, which all points to the fact that the conclusions reached have a general character.

Since the semi-conductor converter power is proportional to the voltage, it means that, by regulating the rotor voltage in the proposed manner, the required converter power is reduced.

4. Conclusions

By regulating the rotor voltage of the induction motor whose speed regulated by double feeding, and which is used for centrifugal pump drive, in the manner proposed in this paper, it is possible to obtain optimal efficiency of a used standard design induction motor of small and medium power and to reduce the required power of the semi-conductor converter, which represents a substantial contribution to the efficiency of the given electric motor drive.

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Original scientific paper

THE SIGNIFICANCE OF POST-HARVEST TRANSPORTATION TASKS IN THE FIELD ROOT VEGETABLE PRODUCTION

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Abstract. *In the paper we present the up-to-date mechanized production technology of carrot production from ridge preparation till harvesting including transporting as well. By the presentation of the performance and economic data of machines necessary for production, we are emphasizing the significant volume of transport tasks in the production technology. Our surveys have proved that the machine work costs of field root vegetable production are high. Considering machine costs it is advantageous if, as in the studied cases, harvesting is done by tractor-pulled working machines instead of expensive self-propelling harvesting machines with high operational costs, as the acquisition cost of connected working machines is more favourable and a better utilization and lower specific operational costs of power machines can be achieved by the use of tractors. It can be stated that special attention is to be paid to the following operations: harvesting, transport, cultivation and plant protection, which are the most costly operations that represent about 95-97 % of the total machine operational costs.*

Key words: *mechanisation, root vegetable production technology, machine investments and usage costs, transportation tasks*

1. INTRODUCTION

Carrot is a very important vegetable for fresh consumption as well as for the deep freezing and for the canning industry [1]. In accordance with the growing methods there is a wide selection of varieties and different production technologies are applied [2, 3].

We present the up-to-date mechanized production technology of carrot production from ridge preparation to harvesting including transporting as well [4].

By the presentation of experiences together with the performance and economic data of machines necessary for production, we are emphasizing the significant volume of transport tasks in the production technology.

2. PRESENTATION OF THE PRODUCTION TECHNOLOGY

The machine technology of production is presented through Table 1 and Table 2. The Table 1 shows the denomination of operation, the machine applied for the certain operation, and the type of the power machine connected to it. Table 2 presents the shift performance of the connected machines. Some of the economic data are also included: the selling price of the working machine and the power machine in the year 2012, the operational cost of the same per shift hour together with the operational cost of the connected machines [5].

Table 1: The machine technology of production of carrot production.

Denomination of operation	Type of machine applied in the technology	
	working machine	power machine
Stubble stripping	Kühne 770 - 7,2 disc harrow	140 kW tractor
Deep ploughing	VN Euromat 3S Var.5blade upright	140 kW tractor
Ploughing-processing	S-2H/M	140 kW tractor
Transport of fertilizer	MBP 6,5	60 kW tractor
Fertilizer spreading	Tornado 5	80 kW tractor
Ridge bed preparation	Rumpstadt FH4x75 RSF 2000 T	140 kW tractor
Sowing	Agricola ANT-3-290	80 kW tractor
Renewal of ridge beds	Badalini Variax EP/85W 140 GLS	80 kW tractor
Spray transport	DETK-115 tanker	60 kW tractor
Plant protection–pre-emergence	HARDI Commander Plus 2200/18	80 kW tractor
Spray transport × 3	DETK-115 tanker	60 kW tractor
Plant protection-post-emergence×3	HARDI Commander Plus 2200/18	80 kW tractor
Spray transport × 6	DETK-115 tanker	60 kW tractor
Plant protection-stock treatment×6	HARDI Commander Plus 2200/18	80 kW tractor
Irrigation	Valmont Linear	
Harvesting	GB-02	80 kW tractor
Crop transport	MBP 6,5	60 kW tractor
Lodging, loading		Telescopic loader
Road transport	HL 92.02 road	Trailer
The type of the machines of the operations of harvesting of carrots meant for ***fresh consumption***		
Harvesting	ASA LIFT Combi - 1000	80 kW tractor

Stubble stripping by disc-harrow is unavoidable in order to work the stem remains of the forecrop into the soil and to prevent weeding. The next operation is deep ploughing. The ploughing is realized in the form of dragging. The subsequent delivery of nutrients is ensured through the transport and spreading of fertilizers. This is followed by the preparation of ridge beds, sowing and later on by the renewal of ridges. Plant protection is applied once as a pre-emergence treatment and three times afterwards as a post-emergence treatment. Stock treatment is applied six times. In the vegetation period of cultivated plants irrigation is necessary in order to achieve a high quality final product and a higher crop yield. This is done by a linear irrigation system [6].

Table 2: The basic economic data of carrot production.

	Shift	Price of		Direct cost of operation		
Denomination of operation	Performance	working machine	power machine	working machine	power machine	total
	(ha/hour)	(EUR)		(EUR/hour)		
Stubble stripping	3	19164	109048	10	27	37
Deep ploughing	1	18000	109048	7	27	34
Ploughing-processing	4,8	7452	109048	7	27	34
Transport of fertilizer	4	6016	13516	2	11	13
Fertilizer spreading	4	9604	82000	6	20	27
Ridge bed preparation	0,6	15200	109048	13	27	40
Sowing	1,5	6400	82000	9	20	30
Renewal of ridge beds	1	6600	82000	6	20	26
Spray transport	4,8	6800	13516	4	11	15
Plant protection–pre-emergence	4,8	21600	82000	12	20	32
Spray transport × 3	4,8	6800	13516	4	11	15
Plant protection-post-emergence×3	4,8	21600	82000	12	20	32
Spray transport × 6	4,8	6800	13516	4	11	15
Plant protection-stock treatment×6	4,8	21600	82000	12	20	32
Irrigation	1	98000		17		17
Harvesting	0,4	66000	82000	44	20	64
Crop transport		6016	13516	2	11	13
Lodging, loading			76000		22	22
Road transport		7536	33720	3	20	22
The basic economic data of the operations of harvesting of carrots meant for ***fresh consumption***						
Harvesting	0,1	59060	82000	34	20	54

In case the final product is meant for canning purposes, harvesting is done by a digging-system root vegetable harvesting machine type, while in case it is meant for fresh consumption by a root vegetable harvesting machine, which can be considered the major machine of the technology and by which picking and stalk removal is done in one course [3, 7].

3. Results of the economic survey

The results of the economic survey of carrot production on a 20 hectare area are shown in Table 3. Apparently, the machine working time necessary for the cultivation of the 20 hectare growing area in case of connected machines has been stipulated related to the individual operations. On this basis, the direct operational cost of the connected machines can easily be calculated by multiplying the *direct operational cost of the machine per hour* (Table 2) with the effective working time. Furthermore, the additional cost of connected machines has also been stipulated which is affected by the capital return on fixed and current assets as well as by the general costs of farming. As a result, the cost of the individual operations related to 20 hectare growing area has been defined the total of which equals the total production costs of carrot production on 20 hectares, and also the specific costs per hectare of the different harvesting methods for fresh consumption or for the canning industry have been stipulated.

Table 3: The economic index numbers of the operations of carrot production on 20 hectares.

	Machine working hours	Cost of operation
	(h)	(EUR)
Stubble stripping	6	265
Deep ploughing	20	814
Ploughing-processing	4	164
Transport of fertilizer	5	75
Fertilizer spreading	5	161
Ridge bed preparation	33	1625
Sowing	13	467
Renewal of ridge beds	20	640
Spray transport	4	70
Plant protection–pre-emergence	4	162
Spray transport × 3	12	214
Plant protection-post-emergence×3	12	489
Spray transport × 6	24	431
Plant protection-stock treatment×6	24	979
Irrigation	20	444
Harvesting	50	4107
Crop transport	150	2299
Lodging, loading	20	515
Road transport	300	7689
Canning industry technology - total	**726**	**21610**
Cost per hectare (EUR/ha)		**1080**
The economic index numbers of the harvesting of carrot the total production technology for ***fresh consumption*** on 20 hectares		
…	…	…
Harvesting	200	14026
Fresh consumption technology - total	**826**	**30602**
Cost per hectare (EUR/ha)		**1530**

It can be stated on the basis of the results that in case of *carrot production for canning purposes* the operational cost of the power machines (6631 EUR) is less than the half of that of the working machines (14.979 EUR). The total operational cost amounts to 21.610 EUR, 1080 EUR per hectare. In case the *goods are meant for the fresh market* the above indexes are as follows: the operational cost of the working machines (14.990 EUR) is nearby equal to the operational cost of the power machines (15.612 EUR). The total operational cost is 30.602 EUR, 1530 EUR per hectare.

It can be stated that the drag picking method harvesting for fresh consumption causes an extra cost of about 450 EUR per hectare.

Concerning the operational cost relations it can be stated that in case the final product is meant for industrial use the *cost of road transport is about 35 %*, and the *delivery from* *the field to the depot by tractor about 10 %* of the total cost. It is followed by the harvesting operation with 19 %. Considering the cost of the other operations of the technology the significant ones are the plant protection with 11 %, the ridge bed preparation with 7,5 %, the deep ploughing and the renewal of ridge beds with 3 % each, while the cost proportion of the remaining operations is often less than 1 %. In case the final product is meant for the fresh market this order is different. The major cost factor is harvesting with 45 %, *road transport and delivery by tractor follows with 25 % resp. 6 %*, and in this case the cost of plant protection is 8 %, of ridge bed preparation 6 %, of deep ploughing 3 % and of the renewal of ridge beds 2 % of the total cost.

The figures of the present survey are calculated on the basis of high quality and mostly valuable power machines which ensure effective performance. Consequently the acquisition and operational costs of the power machines are also substantial [8]. The prescribed operations can naturally be realized by using power machines of a lower technical level under strict control and in this case the operational cost of the machines can be less than that observed in the survey.

The investment cost of the machines applied in the production technology amounts to 602 thousand EUR *(554 thousand EUR*[1]), out of which the purchasing price of the working machines amounts to 288 thousand EUR, which equals about 48 % of the total investment cost *(292 thousand EUR – 53 %)*, while the purchasing price of the power machines is 314 thousand EUR, about 52 % of the total cost of machines *(262 thousand EUR – 47 %)*. In case of power machines it can be stated that one power machine with an engine capacity of 140 kW is needed for the hard cultivation works, while the tasks of nutrients delivery, plant protection and crop cultivation, sowing, harvesting tractor delivery are fulfilled by 80 kW main and a 60 kW aid machine. For moving the goods in the depot a *telescopic loader is also required,* first of all in case of root vegetables meant for industrial use. For the road transport of the crop a *low-cost trailer can be used*. With the above method of applying power machines lower acquisition costs and a more effective utilization of power machines can be achieved.

Carrot production on 20 ha demands 726 shift hours of machine work, out of which the two lower capacity tractors represent a great proportion due to delivery of nutrients, sowing, ridge bed renewal, crop protection and harvesting and *transport by tractor* and the shift hour performance of the high capacity power machine in the course of cultivation is also significant. *Road transport with its 300 shift hour capacity demand is the most time-demanding operation* [9].

In case of production meant for fresh consumption the 80 kW tractor works even more shift hours due to the time-demanding harvesting. In this case the total number of the shift hours performed in the course of the technology is 826.

4. CONCLUSIONS

The surveys conducted have proved that the machine work costs of field root vegetable production are high [10]. Taking into consideration the extra work connected to grading and consumer packing substantial additional costs arise which can lead to specific costs per hectare exceeding 1500 EUR. In case of a 60 t/ha yield it can easily be calculated that operational costs of machines themselves exceed 3 EURO Cent/kg, and

[1] Investment cost values in case of technology when the goods are meant for the fresh market.

we have to take into consideration the costs of seeds, fertilizers, pesticides, labour and irrigation water.

Considering machine costs, it is advantageous if, as in the studied cases, harvesting is carried out by tractor-pulled working machines instead of expensive self-propelling harvesting machines with high operational costs, as the acquisition cost of connected working machines is more favourable and a better utilization and lower specific operational costs of power machines can be achieved by the use of tractors.

It can be stated that special attention has to be paid to the following operations: harvesting, transport, cultivation and plant protection works which are the most costly ones and which represent about 95-97 % of the total machine operational costs.

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Original scientific paper

METHODOLOGICAL IMPROVEMENT OF LABORATORY SPECTROSCOPY FOR POSTHARVEST SEPARATION OF FUSARIUM INFECTED GRAIN SAMPLES

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Abstract. *In common alimentation habit most cereals are consumed in refined form. The separation of kernel outer layer (bran and germ and endosperm removal) during the grinding and refining process results in the so called "white flour". This means decisive loss of useful nutrients and elements. Due to the modern healthy alimentation trends the scale of the "whole flour" increases. "Whole flour" also contains the above mentioned components so it is more robust, full-flavored flour with valuable vitamins, minerals and more protein. The part of the trend is the growing demand toward organically or ecologically produced and treated foods such as ecological whole grain products. Due to the strict regulation of such production lines the chemical protection against fungal diseases is rather limited, nevertheless, seeds infected with fungal disease - if not separated properly from the raw material - can cause serious health problems. In this study we are introducing a basic study which aims to identify the optical characteristics of Fusarium infected wheat samples to facilitate an effective non-destructive separation method.*

Key words: *whole grain products, Fusarium, postharvest selection, spectroscopy*

1. INTRODUCTION

As the trend of healthy alimentation grows the production and marketing of whole grain products are rises. More and more people pay attention to change to these products. In accordance with the spreading of another decisive tendency, which might be called bio-trend-line, the demand toward ecologically produced whole grain products is rising. Due to the bran content of such foods the risk of health problems caused by various fungal diseases and toxins increases. This must be considered as important hazard factor. The strict regulation of chemical protection makes difficult to guarantee the fungal disease-free production of cereals so decisive quantity of the grain cannot be qualified as sound raw material for further processing. Beside the resistant or tolerant varieties and the favourable climate conditions one solution is the postharvest selection, the separation of sound and infected kernels. The traditional laboratory technologies are rather time, cost and labour-intensive methods and not capable of performing high speed selection which – considering the usual harvested quantity - is necessary to reach a desirable effectiveness.

A possible solution for the separation is the remote sensing. One of these non-destructive analytical technologies is the spectroscopy, which studies the interaction between electromagnetic radiation and matter (Fig 1.).

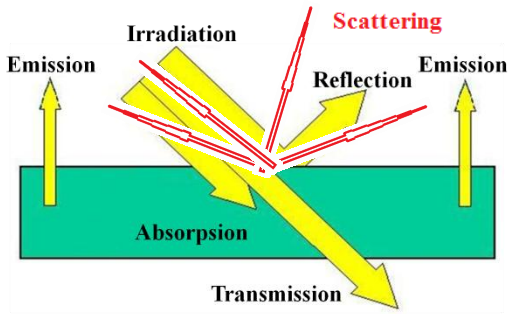

Fig. 1: EM interactions (NOAA Coastal Service Center (2007) modified).

The method of evaluating the spectral characteristics of different biotic or abiotic materials and surfaces originates in the laboratory spectroscopy, where it is generally used in physical and analytical chemistry hence atoms and molecules have unique spectra. Emission is characteristic to atomic bonds while absorption refers to molecular bonds. It provides opportunity to obtain quantitative relationships between the environmental and physiological parameters of organic or non-organic samples, plant parts, soil quality parameters and the features of reflectance spectra [1-7] (Fig. 2).

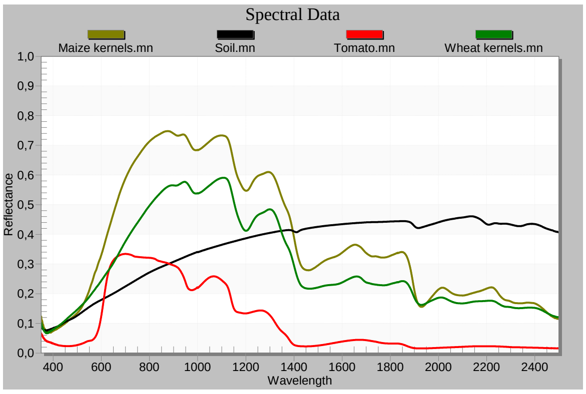

Fig.2: Distinctive spectral features of different samples.

Characteristic wavelengths can indicate changes in moisture content [8] and other relevant parameters [9, 10]. Though, the processing of these images is a very complex procedure [11].

Based on scientific references spectral evaluations were proved to be useful in detecting and diagnose certain fungal diseases [12, 13]. Five different fungi species were separated (*Penicillium chrysogenum, Fusarium moniliforme* (syn.: *F. verticillioides*), *Aspergillus parasiticus, Trichoderma viride* and *Aspergillus flavus*) under laboratory conditions [14]. Researches showed correlation with fusarium infection and level of infection in case of winter wheat kernels between 450 and 950 nm [15]. Characteristic absorption peaks were detected at sound – 1450 nm and 2100 nm – and infected – 2300 nm and 2350 nm - maize samples [16].

In the well-equipped remote sensing laboratory of the Hungarian Institute of Agricultural Engineering beside the airborne sensor system an ASD FieldSpec 3 Max portable spectroradiometer is used. The equipment can widely be used both in field and under laboratory conditions. It is adequate to carry out independent, fast and precise evaluations in an economic way. The device extends the range of the detectable visible light [17, 18] to NIR (near infrared) and the SWIR (shortwave infrared) region and covers the range of 350 to 2500 nm [19].

In order to develop a spectral reflectance based separator a high and precise decision making system is necessary. To facilitate and reduce the time of data processing the most informative wavelengths should be identified. Wavelengths on which the Fusarium infection can be detected and separated from sound kernels. For this the exclusion of common errors in measuring protocol and the reduction of usual standard deviation are inevitable.

In this study we are introducing the preliminary results of an improved measuring methodology that has decisively reduced the uncertainties of reflectance spectroscopy.

2. Material and methods

For laboratory tests we constructed and use a light-isolated cabinet where disturbing environmental light is shielded. The ASD Field Spec®3 MAX portable spectroradiometer and the laboratory cabinet are presented in Fig. 3.

Fig. 3: ASD Field Spec®3 MAX and the light-isolated cabinet.

Two methods of data acquisition are possible according to the size and physical parameters of the object to be tested. ProLamp (Fig. 4) is usually used to illuminate objects from a distance of 30-70 cm. Measurements of small object areas can be carried out with PlantProbe sensor-head (Fig.5) which has internal light source.

Fig. 4: ProLamp.

Fig. 5: PlantProbe.

In this study we have evaluated the stability of results – at ProLamp - received by putting back the same sample. Results showed rather high variation between the spectra Fig. 6 and Fig. 7.

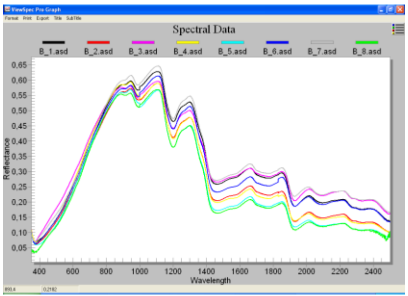

Fig. 6: Reflectabce spectra of the same wheat sample.

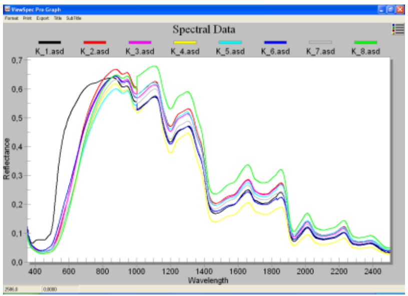

Fig. 7: Reflectance spectra of the same maize sample.

Based on our theory, such difference was caused by the inhomogeneity of the illumination.

The original ProLamp provided a simply one-sided and only partially homogenous illumination. Upon the preliminary results the surficial changes in the micro-relief of the sample affects the recorded spectra. This affect had been tested by rotating the samples by 0°, 90°, 180°, 270°. The change in light/shadow balance definitely increases the uncertainty. These factors have been risen a need for designing a new illumination. The following demands have been laid toward the new illumination:

- provide electromagnetic radiation throughout the range of 350-2500 nm;
- well focused;
- homogenous and
- positioning possibility (illumination angle).

Focus, homogeneity and spectral distribution were examined. Results are illustrated with figures Fig. 8 and Fig. 9.

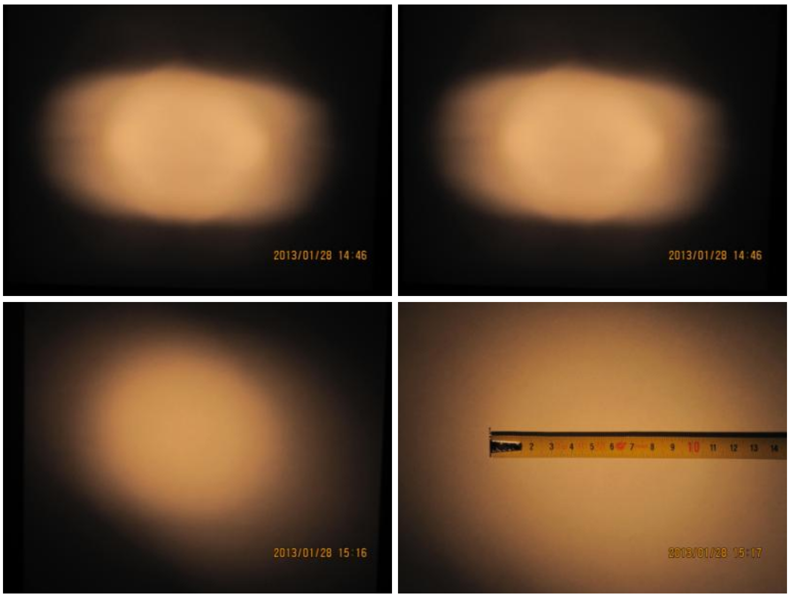

Fig. 8: Testing the projections of different solutions: most homogenous projection is visible below, with a diameter of 10 cm.

Several housings and illuminants were tested. Finally, according to the tests, a 12 V 55W halogen illuminant and a 84 mm in diameter housing were chosen, due to its optical characteristics (spectral distribution, and homogenous trajectory).

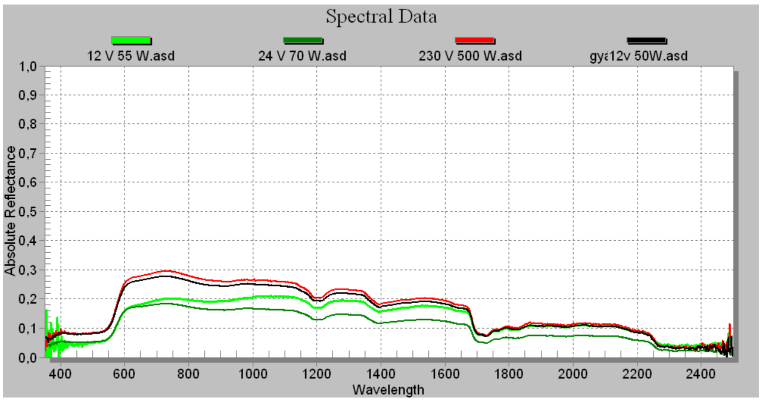

Fig. 9: Testing the spectral distribution (reflectance) of different illuminants.

After the best configuration had been selected a special frame was designed and manufactured to hold 8 pieces of lamps. This frame was installed inside the light isolated laboratory cabinet (Fig. 10). Light was focused directly to the sample plate.

Fig. 10: The new illumination system.

3. Results and discussion

After developing the above described illumination system we repeated the measurements with the same maize and wheat samples, with the same number of repetition. The differences between the spectra, which were recorded from the same sample, but from various angles, reduced significantly. The reduction of the calculated standard deviation is illustrated with Fig. 11 and Fig. 12.

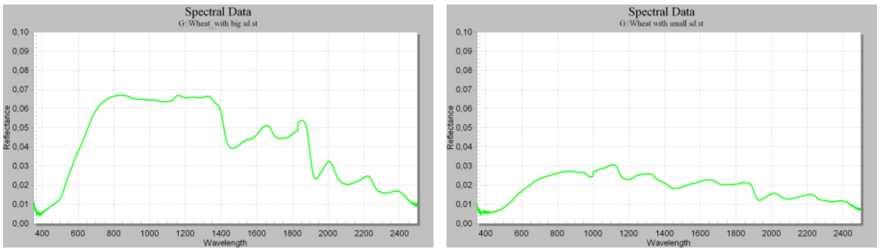

Fig. 11: The reduction of standard deviation in case of wheat. Measurement with new illumination - on the right.

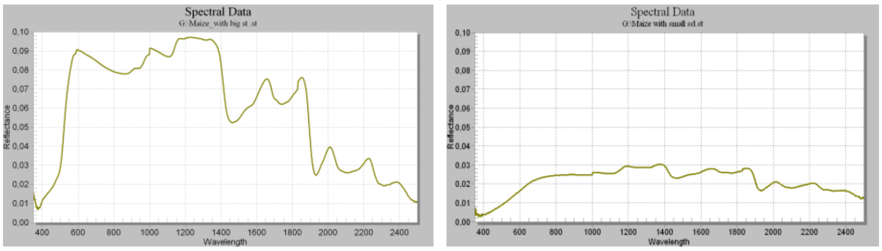

Fig 12: The reduction of standard deviation in case of maize. Measurement with new illumination - on the right.

Results show notable reduction of uncertainity. The well focused, homogenous and multidirectional illumination can significantly increase the precision of the measurement. Nevertheless, by using the appropriate normalization techniques during preprocessing the spectral data can further increase the reliability. This facilitates to detect and identify even smaller differences, characteristics referring to existed infection of kernels.

4. CONCLUSIONS

The paper presents results of studying the possibility of postharvest identification and separation of fungal disease infected maize or wheat kernels. By the preliminary experiments the precision of the measurement method, or rather the technical background needed some improvements. The theory that assumed the quality and the direction of the illumination as a relevant factor in the reliability of the measurement has proved to be right. The newly developed illumination system provides eight-directional, homogeny light. By using this type of illumination during the measurements the authors managed to decrease the standard deviation of the measurements significantly. This advance in precision will facilitate the further study and identify fusarium infection sensitive wavelengths and characteristics which can be used to separate infected and sound kernels.

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Scientific review paper

ERGONOMICS APPROACH TO EVALUATE SAFETY RISKS WITHIN THE UK FOOD INDUSTRY, PRELIMINARY RESULTS

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Abstract: *Generally ergonomics, a science concerned with the 'fit' between people and their work, could considerably reduce injury risks improving productivity and reducing wastes. To assess the fit between a person and its work, a range of factors have to be considered including: job task, individual both physical and psychological characteristics, organization and social environment. In this paper the authors aim to understand how ergonomics and human factors can improve health and safety within the UK food industry. The aim was to identify hazards and risk within the industry and ways to reduce or eliminate dangerous situation. In conclusion author observed that ergonomics has both a social goal (well-being) and an economic goal (total system performance); that ergonomics considers both physical and psychological human aspects; and that ergonomics is looking for solutions in both technical and organizational domains.*

Key words: *ergonomics; health & safety; injury; work related illness.*

1. INTRODUCTION

1.1 Ergonomics evolution

Over the last 50 *year*s, ergonomics, a term that is used here synonymously with human factors (HFE) has been evolving as a unique and independent discipline. Today, HFE is the discipline that focuses on the nature of human-artefact interactions, in terms of unified perspective of the science, engineering, design, technology and management of human-compatible systems.

Historically, the philosophical framework for the unique discipline of ergonomics (ergon + nomos), or the study of work, was introduced by the Polish scientist W.B.

Jastrzebowski (1857). Ergonomics was proposed as a scientific discipline with a very broad scope and a wide area of interests and applications, encompassing all aspects of human activity, including labour, entertainment, reasoning and dedication (Karwowski (1991, 2001).

The contemporary ergonomics discipline, independently introduced by Murrell in 1949 (Edholm and Murrell 1974), was viewed at that time as the applied science or technology, or both. The ergonomics discipline promotes a holistic, human-centred approach to work systems design that considers physical, cognitive, social, organizational, environmental and other relevant factors (Grandjean 1986, Wilson and Corlett 1990, Sanders and McCormick 1993, Chapanis 1996, 1999, Salvendy 1997, Karwowski 2001, Vicente 2004, Stanton et al. 2004). The International Ergonomics Association (2003) defined ergonomics or HSE as: *"...the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human wellbeing and overall system performance".*

1.2. Occupational Ergonomic

In the view of the IEA ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people (IEA, 2003).

HFE aims to optimize human well-being and overall system performance. HFE discovers and applies information about human behavior, abilities, limitations and other characteristics to the design of tools, machines, systems, tasks, jobs and environments for productive, safe, comfortable and effective human use (Sanders and McCormick 1993, Helander 1997). In this context, HFE deals with a broad scope of problems relevant to the design and evaluation of work systems, and working environments in which human-machine interactions affect human performance and product usability.

1.3. Ergonomics Health and Safety

The HFE discipline advocates: *". . . systematic use of the knowledge concerning relevant human characteristics in order to achieve compatibility in the design of interactive systems of people, machines, environments, and devices of all kinds to ensure specific goals . . ."* (Human Factors and Ergonomics Society 2004).

Typically, such goals include improved (system) effectiveness, productivity, safety, ease of performance and the contribution to overall human well-being and quality of life.

The quality of working life and the system (enterprise) performance is affected by matching of the positive and negative outcomes of the complex compatibility relationships between the human operator, technology and environment. Positive outcomes include such measures as work productivity, product quality human well-being, etc. The negative outcomes include both human and system-related errors, accidents, injuries, physiological stresses and subjective psychological (undesirable) behavioral outcomes job/occupational stress, etc.

1.4. Objectives and Aims

It is proposed this would be achieved by the following objectives:

- to observe and analyze how small medium and large companies carry out risk assessment in the workplace, prevent accidents and cases of work- related ill health;
- to observe if the extent of participation of workers helps the Companies to identify and spot risks and hazard; and
- analyze the risk assessment from the point of view of both managers and workers.

The aim of this paper is to highlight that ergonomic principles applied to risk assessment and health and safety management influence the behavior at work in a way which can prevent and avoid risk that might affect workers' health and safety.

2. MATERIAL AND METHODS

In order to better understand how ergonomics and human factors can improve health and safety within the UK food industry the authors visited a number of different companies involved in food and drink production to observe current working practices and obtain information, via questionnaires, about the risks and solutions adopted within the working environment from relevant personnel including workers, health and safety officers and management.

2.1. Companies Selection

To collect data we planned to visit a number of different companies, involved in food production located in and around Milton Keynes and Melton Mowbray. In Milton Keynes, with the assistance of the local Councils' Enviroment Health Office, a list of companies that could provide assistance was produced. These companies were then contacted to enquire is they would be willing to participate in the project. A similar list was drawn up of companies in Melton Mowbray. The companies were of different sizes, some with more than 200 employees, others with less than 20 employees. They were also involved in food production including dairy, meat, bakery, brewery and soft drinks production.

2.2. Questionnaire

The aim was to identify hazards which affect workers' health and safety and we used two main method, one of the two used for data acquisition consisted of a questionnaire. Questions were prepared under several categories, with 67 questions divided into following general section: i) workers and company data, ii) feeling about health and safety, iii) relationship between job and health, iv) health and safety in their own organization, v) knowledge about mechanical hazards, plant and machinery, vi) risks during working.

We asked workers and H&S manager to agree/disagree with a series of questions under each section using a 5-point Likert scale and provide more extensive answers to others. Questionnaires were submitted to workers and health and safety managers, via email or personal contact.

2.3. Walk trough in site and discussion

Information was also gathered during walk-through of companies the study team was able to visit, in the company of a responsible of staff. During each visit was to observe and record current work practices, both overt and covert, what safety notices were displayed, what mechanical guards were provided and whether notices were displayed. During the visit the company representative was also asked about their beliefs about health issues, working practices, company health and safety, and provision of personal protective equipment (PPE). In addition information was collected about current H&S procedures, plants and machinery, automation and control of manufacturing processes

2.4. Ethical Approval

The study was approved by Cranfield University's Science and Engineering Research Ethics Committee. All information collected through remains strictly confidential.

3. RESULTS AND DISCUSSION

Collected data were classified and analyzed together with the data from previous research and data from the literature in order to present some preliminary results of larger ongoing project. From analysis of the questionnaire data and from interview of health and safety manager it was possible to verify that on average, a risk management framework is frequently adopted by managers to guide the application of the principles of ergonomics to any particular problem.

From a healthy and safety managers' perspective, the emphasis for risk control is on elimination or reduction of risk through design controls rather than administrative controls such as training, selection or personal protective equipment PPE doing all reasonably practicable.

Most important, the risk management process also places emphasis on consultation with the people concerned at each step. This issue is at the heart of ''participative ergonomics'' approaches, which take as an underlying assumption the notion that the people involved are the ''experts'' and must be involved at each stage of the risk management cycle if the process is to be executed successfully.

In an occupational injury management context, this implies in particular that employees and management participate through hazard identification, risk assessment, risk control and review steps of the risk management cycle.

In the scientific literature there are several studies explaining why workers' participation is important in this step and in all challenge to make safety their life at work. Participative ergonomics has been used to create more human centered work and to improve work organizational climate, as well as to prevent musculoskeletal disorders associated with manual tasks.

Analyzing the preliminary data, risk factors are in jobs requiring repetitive, forceful, or prolonged exertions of the hands; frequent or heavy lifting, pushing, holding, pulling, or carrying of heavy objects; and prolonged awkward postures. All these activities are defined 'manual task'. Vibration and cold may add risk to these work conditions.

Jobs or working conditions presenting multiple risk factors will have a higher probability of causing occupational ill health as musculoskeletal problem work-related stress, which is often cited as a cause of mental ill health, occupational asthma and rhinitis, and noise-induced hearing loss. The level of risk depends on the intensity, frequency, and duration of the exposure to these conditions. Environmental work conditions that affect risk include intensity, frequency and duration of activities, but in this paper we considering preliminary result on risk from exposure noise level.

Risks can be eliminated or reduced by application of ergonomics' best practice, reducing error and influencing behavior, such that have been observed during the visits.

We can thus distinguish and classify manual handing, activities that subject the workers to hazardous substances exposure or high levels of noise, we also consider working activities potentially dangerous because they took place in a work environment unsuitable.

All these work activities are able to affect workers' health and safety if companies don't control and make solutions about them.

3.1. Manual handling

The risk factors considered by health and safety managers and workers to be important in assessing the impact of manual handling, especially in terms of musculoskeletal disorders (MSD) are:

- Frequency and repetition,
- Force and
- Working posture.

3.1.1. Frequency and repetition

Repetitive tasks are typically found in assembly, production, processing, packaging, packing and sorting work, as well as work involving regular use of hand tools. Repetitive work contribute to the development MSDs. From the walk trough, and from questionnaire data we could observe that main repetitive tasks were:

- lifting and carrying sacks, ingredients, boxes, packaging;
- lifting and handling drums of liquid and casks.

The companies aware of task risks try to reduce the consequences.

In order to reduce the risk companies, especially large ones indicated they:

- use automation and mechanization to do the highly repetitive functions and leave more varied jobs for the workers;
- use Task rotation to manage the risk of repetitive work;
- reduce the number of repetitive movements and the rate at which they are made, especially when combined with applying force and/or in awkward postures.

Where mechanization is not possible, most of the companies involved in this project introduce measures to prevent injury, i.e. improved ergonomic design of work stations and work areas, job rotation, especially:

- ➢ power tools in place of manual tools;
- ➢ task design: break up long periods of frequent repetitions and static inactivity with frequent pauses;
- ➢ spread repetitive task elements and movements across both hands;
- ➢ share repetitive work through teamwork or task rotation;
- ➢ distribute the workload over different muscle groups and joints.

3.1.2. Force

We asked people if they use force in combination with poor posture in their work activities, and to describe manual handing they considering more fatiguing. From collected data results that the most activities are:

- hands lifting;
- putting down.

We could observe that companies involved apply ergonomics principles to reduce consequences of fatiguing work such as:

- reduce the forces required i.e. use other power sources rather than muscle power;
- reduce the frequency with which force needs to be applied;
- reduce the time spent applying force. This especially relates to static forces that applied and sustained for steadying or supporting items or gripping tools; and considering altering the position or orientation of work pieces or tools so that any force can be applied more easily and efficiently improves the posture of the workers when applying forces.

3.1.3. Working posture

From collected data, to reduce awkward posture, the ergonomics principles that companies involved apply are:

- reduce the time spent holding and/or repeating awkward postures;
- avoid using static postures for prolonged periods; and
- ensure workplaces and work equipment are designed or selected to account for difference in size, shape and strength of workers.

3.2. Workplace health and safety

3.2.1. Noise

Noise at work can cause hearing damage that is permanent and disabling. Hearing loss can be gradual because of exposure to noise over time, but also damage caused by sudden, extremely loud noises.

From collected data result that in the companies where there is noise, especially in drinks production and in large bakeries, they make sure the legal limits on noise exposure are not exceeded, complying the law and looking for alternative processes, equipment and/or working methods which would make the work quieter or mean people are exposed for shorter times. Large companies also took action to reduce noise exposure with a planned program of noise control, as ergonomics principles suggest.

Perceiving causal links among risk awareness, behavior, and exposure constitutes a very important issue in the control of exposure, either by avoiding it (whenever possible) or by using PPE.

The types of precautions companies took to reduce the workers' risks included:

- quieter equipment or a different, quieter process;
- engineering/technical controls to reduce, at source, the noise produced by a
- machine or process;
- using screens, barriers, enclosures and absorbent materials to reduce the noise on its path to the people exposed;
- designing and laying out the workplace to create quiet workstations;
- improved working techniques to reduce noise levels;
- limiting the time people spend in noisy areas.

Most of companies involved in our project, especially the larger ones, use all of the mentioned solutions.

There are different types of hearing protective used by the companies:

- earmuffs;
- earplugs;
- semi-inserts/canal caps.

Companies should take into account the hearing protectors has a suitable protection factor that is sufficient sufficient to eliminate risks from noise but not so much protection that wearers become isolated.

Walking trough we could observe that companies:

- identify hearing protection zones – areas of the workplace where access is restricted, and where wearing hearing protection is compulsory;
- provide employees with hearing protectors, and also they do that if they ask for them;
- consider the work and working environment, i.e. physical activity, comfort and hygiene compatibility with other protective equipment, i.e. hard hats, masks and eye protection;
- companies enforce wearing of ear defender, in fact during a walk through with H&S Officer, one member of staff was reprimanded for not wearing any protection and asked him to immediately leave the production area to where noise are not a H&S issue.

We consider that companies are very careful to ensure that employees wear hearing protector, fully and properly. By this way company must provide health surveillance for all your employees who are likely to be frequently exposed above the upper exposure action values, or are at risk for any reason, i.e. they already suffer from hearing loss or are particularly sensitive to damage.

Company should periodically review their arrangements and achievements in managing competence, and implement improvements as required.

3.3. Environment workplace health and safety

The term workplace also includes the common parts of shared buildings, private roads and paths on industrial estates and business parks, and temporary. The condition of the buildings needs to be monitored to ensure that they have appropriate stability and solidity for their use.

We were considered in the questions submitted: floors and traffic routes, slips and trips, falls from height.

3.3.1. Traffic routes and floors

Walking through we could observe as the big company to allow people and vehicles to move safely, keep vehicles and pedestrians apart by ensuring that they use entirely separate routes. If people and vehicles have to share a traffic route, they use kerbs, barriers or clear markings to designate a safe walkway and, where pedestrians need to cross a vehicle route, provide clearly marked crossing points with good visibility, bridges or subways. Signs were also present telling drivers of vehicles to sound their horns warning pedestrians of their presence. We consider that the best approach ensuring safety workplace.

Floors and traffic routes should be sound and strong enough for the loads placed on them and the traffic expected to use them. The surfaces should not have holes or be uneven or slippery, and should be kept free of obstructions and from any article or substance which may cause a person to slip, trip or fall.

We observed in one company that took best practice to ensure safety traffic routes, that in an area where they were cleaning machinery they neglected to put 'Wet Floor' warning signs in place to attract attention of the hazard to the workers to avert potential risks to slipping or tripping. The authors also walked through the area without being told to take care, although it was patently obvious the floor was wet and potentially dangerous.

From data collected data, it was evident that workers and H&S officers received health and safety advice about slips and trips, and consider their work environment susceptible to slips and trips hazard. About precautions that company takes to reduce slips and trips hazard the most common answers were:

a) cleaning regime that ensures floors are kept free of contamination;
b) if the floor is too slippery, anti slip trips are put down.

3.3.2 Ventilation

General working environment of people in the workplace take into account environmental factors such as humidity and sources of heat in the workplace combined with personal factors such as the clothing a worker is wearing and how physically demanding their work is to influence what is called someone's 'thermal comfort'.

Walking through with H&S Officer at one company, we were told of one situation where high concentrations of CO_2 accumulated due to large number of people working in an unventilated area, leading to increased drowsiness especially in the afternoon, and as a consequence they increased ventilation.

CONCLUSIONS

When address human factors in relation to health and safety, aim to optimize human performance and reduce human failures. Organizations need to take a proportionate approach to human factors in risk assessment based on their hazard and risk profile. Identifying the potential for human failure in preventing an accident or exposure to substances hazardous to health requires having a thorough understanding of the task the person is carrying out.

To prevent or reduce the chance of such failures you have to know what the failures are and what causes them. These failures form a 'chain' that leads from people in the company who made decisions long before an incident or accident to the person who seems to be immediately responsible. The understanding of this chain is needed in order to move logically forwards along it – to do risk assessments; and backwards – to do accident investigations.

Applying ergonomics to the workplace can reduce the potential for accidents, reduce the potential for injury and ill health and improve performance and productivity.

Taking account of ergonomics and human factors can reduce the likelihood of an accident. Ergonomics can also reduce the potential for ill health at work, such as aches, pains and damage to the wrists, shoulders and back, noise-induced hearing loss and work-related asthma. The layout of controls and equipment – they should be considered positioned in relation to how they are used. Placing those used most often where they are easy to reach without the need to stoop, stretch or haunch. Making sure protective measures such as extraction hoods or respirators are easy and comfortable to use means they are more likely to be effective at reducing exposure to hazardous substances.

The information collected highlights how companies involved in the our project avoid many well-known accidents following ergonomics principles, but sometimes they don't pay much attention to the potential risk of hazards, such as in the case of the missed signboard "wet floor". Many accidents might have been prevented if ergonomics and human factors had been considered in designing people's jobs and the systems they worked in.

The conclusion is that proper consideration of 'human factors' is a key ingredient of effective health and safety management. Human factors interventions will not be effective if they consider these aspects in isolation. The scope of what we mean by human factors includes organizational systems and is considerably broader than traditional views of human factors/ergonomics. Human factors can, and should, be included within a good safety management system and so can be examined in a similar way to any other risk control system.

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Original scientific paper

CHANGES IN PHYSICAL PROPERTIES OF CARROT ROOT AFTER OSMOTIC DEHYDRATION

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Abstract: *Physical properties of carrot root were investigated based on the changes in mass, volume, moisture content on wet base, mechanical properties and color. Osmotic drying was carried out at a temperature of 40 and 60°C and concentration of sucrose solution of 50 and 65°Bx, three hours. The carrot root was sliced at 10 mm. Samples were pretreated with 4% malic acid (20 minutes) at temperature 20°C, water blanched at temperature 90°C (3 minutes) or without pretreatment.*
Blanched samples had lower values of the physical properties in reference to fresh or pretreated samples with malic acid. Applying osmotic dehydration, statistical significant differences in mass, volume, moisture content and mechanical properties were found. Moisture content after 3 hours of osmotic dehydration was in range 69.40% to 47.15%, with regard to temperature and concentration of sucrose solution. Testing the color, there was not found statistical significant differences after osmotic drying.

Key words: *physical properties, mechanical properties, carrot root, osmotic dehydration*

1. INTRODUCTION

There are several reasons why food physical characteristics are measured: engineering process design, determination of structure and texture. It has been generally accepted that the texture represents a sensory characteristic since only humans can measure food texture [1]. Solid food such as apple or carrot shows the highest correlation between the sensory firmness and puncture or compression test [2].

Many authors suggest time intervals (120-240-300 minutes), the concentration of sucrose solution (40%, 60% and 80%) and temperature (35-55°C or 60°C) in osmotic dehydration process [3, 8]. Both higher concentration of solution and higher treatment time allow greater moisture loss increasing dry matter content [3]. Higher treatment time and treatment temperature had significant effect reducing the volume of the product [7].

Carrot roots are used fresh or with different levels of processing. Convective drying method is the most usually used, but there is a complete degradation of the texture and the loss of many nutrients and high quality materials. Carrot root has great importance in the human diet and is necessary to explore new opportunities of carrot root processing. One of them, unexplored, is the osmotic dehydrated carrot roots in sucrose solution. This would create a new group of products, which have a great importance in the diet.

Nomenclature:

PT – pretreatment,
OD – osmotic dehydration,
W – without pretreatment,
MA – pretreatment 4% malic acid,
B – pretreatment blanching,

Δm – changes in mass (-),
ΔV – changes in volume (-),
Δw – changes in water content (-),
ΔA – changes in load (-),
ΔFyp – changes in puncture force (-),
ΔL – changes in slope of puncture curve (-)

2. Material and methods

Carrot hybrid ‘bolero F1’, produced on farm in Begeč, was used in this research. Prior to the beginning of any tests the entire carrot root was washed and stored at a temperature of 4°C for 24 hours. Fresh cut slices 10 mm thickness were used. Three different pretreatments were applied. The carrot slices were immersed in malic acid (4%) for 20 min (PTMA), or blanched (PTB) for 3 min at a temperature of 90°C or without pretreatment (PTW). Osmotic dehydration was performed for 3 hours at temperature 40°C with sucrose concentration of 50°Bx or 60°C and 65°Bx, in a laboratory dryer. Mechanical properties were analyzed with TMS-PRO measuring device according puncture test with a cylindrical punch (4 mm in diameter) at penetration depth of 5 mm. Color measuring in this experiment was performed with a three-filter colorimeter [Konica Minolta CR-400]. Mass was measured with electronic scale of 0.01 g accuracy, and volume was determined by method of immersion into liquid (distilled water). Determination of sample’s dry matter content and moisture was done during the drying performed in convection dryer at 80°C for 24 hours. Testing was performed in the Laboratory for Biosystematics Engineering, Department of Agricultural Engineering at the Faculty of Agriculture in Novi Sad. The changes in mass, volume, dry matter content and load puncture was calculated as ratio between currently measured value and starting value without pretreatment. Statistical data processing was done with ANOVA and Duncan’s tests at the significance threshold of 5%. "Statistica 12" program [StatSoft, Inc] was used for the analysis.

3. Results and discussion

3.1. Changes in carrot root mass, volume and moisture content

For testing we used fresh root mean mass 149.5 g, length 209.9 mm and 89.57% moisture content. In the case of the pretreatment with malic acid (PTMA), there was a statistically significant difference in the change of mass, density and moisture content of carrot roots (Table 1).

Table 1: Changes in carrot root mass, volume and moisture content depend on pretreatment and osmotic dehydration.*

Treatment	OD	Δm	ΔV	Δw
W	*40°C 50°Bx*	*1,00* [a]	*1,00* [a]	*1,00* [ab]
	60°C 65°Bx	*1,00* [a]	*1,00* [a]	*1,00* [ab]
	Average	**1,00 a**	**1,00 a**	**1,00 a**
PTMA	*40°C 50°Bx*	*1,00* [a]	*1,01* [a]	*0,99* [b]
	60°C 65°Bx	*1,00* [a]	*0,99* [a]	*1,00* [ab]
	Average	**1,00 a**	**1,00 a**	**1,00 a**
PTB	*40°C 50°Bx*	*0,92* [b]	*0,92* [b]	*1,00* [ab]
	60°C 65°Bx	*0,93* [b]	*0,92* [b]	*1,01* [a]
	Average	**0,92 b**	**0,92 b**	**1,00 a**
ODW	*40°C 50°Bx*	*0,60* [d]	*0,55* [d]	*0,77* [c]
	60°C 65°Bx	*0,43* [f]	*0,36* [ef]	*0,55* [g]
	Average	**0,51 d**	**0,45 c**	**0,66 b**
ODMA	*40°C 50°Bx*	*0,61* [d]	*0,55* [d]	*0,72* [e]
	60°C 65°Bx	*0,41* [g]	*0,35* [f]	*0,53* [h]
	Average	**0,51 d**	**0,45 c**	**0,63 b**
ODB	*40°C 50°Bx*	*0,69* [c]	*0,57* [c]	*0,74* [d]
	60°C 65°Bx	*0,48* [e]	*0,38* [e]	*0,56* [f]
	Average	**0,59 c**	**0,48 c**	**0,65 b**

* Testing conducted by columns by Duncans's test at the threshold of 5% significance.

Blanching (PTB) resulted in statistically significant changes in weight and volume, while at the same time there has been no change in moisture content of the sample. After osmotic dehydration (OD) there have been significant changes in weight, volume and moisture content of carrot roots. Changes in weight, volume and humidity were less pronounced if the blanching pretreatment was applied. Moisture content depends on both temperature and concentration solution after osmotic dehydration. For blanched samples were 66.96% and 50.06%. For samples treated with malic acid measured values were 65.15% and 47.15%. For samples without any pretreatment were 69.40% or 48.96%.

3.2. Changes in carrot root mechanical properties

The pretreatment and osmotic dehydration lead to a deformation of the sample. For this reason, the puncture test [4] was used as the most appropriate test to evaluate the mechanical properties of carrots slices. Measurement of force penetrating punch is derived for the path length of 5 mm, speed 30 mm/min. In the cross section of carrot root, it is possible to clearly distinguish two parts: the xylem and phloem. Testing was performed separately for xylem and phloem. On the curve resistance penetration depending on the distance, there is a characteristic point (yield point, the value of penetration resistance rapidly decreases). There was found difference in structure between the parts of carrot root (Fig. 1). Penetration force carrot root at measuring place on phloem reaching the yield point and continues to grow (curve type A) or retain the same value (curve type B). Penetration of punch in the xylem, obviously no clearly expressed yield point (type D curve), or force value remains the same (type B) or decreases (type C).

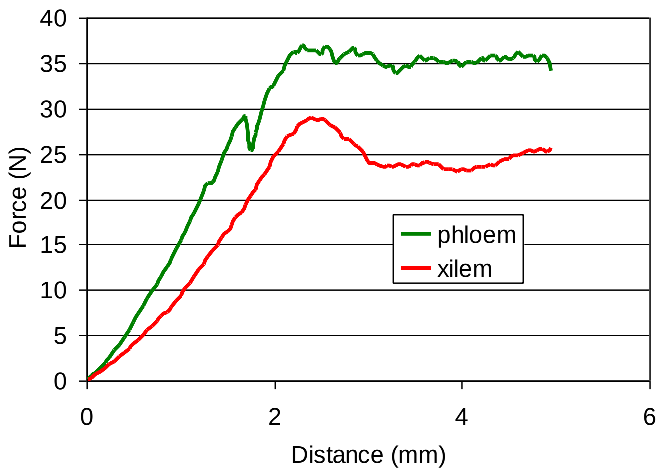

Fig. 1: Puncture force in relation to measuring place.

Testing the statistical significance of the applied load at a distance of 5 mm, the values of puncture force at the point yield point and the slope of the curve force-distance to the yield point, there were no statistically significant differences between the xylem and phloem, so this factor in further analysis is not specifically discussed, but rather as a comparison.

Changes of mechanical properties were measured by changing load (ΔA), the puncture force in section yield point (ΔFyp) and the slope of the curve force-distance (ΔL) to the point yield point. The samples with malic acid come up to the decrease of the value of the measured mechanical properties. Blanching samples values had strong fall in 0.44; 0.57 and 0.56. The same dependence was determined after osmotic dehydration. For osmotic dehydrated without pretreatment (ODW) and samples treated with malic acid (ODMA), there was found statistically equal values for measured parameters ΔA and ΔL. For blanched and osmotic dehydrated (ODB) samples were measured the higher and the statistically significant changes.

Table 2 Changes in carrot root mechanical properties depend on pretreatment and osmotic dehydration.*

Treatment	OD	ΔA	ΔFyp	ΔL
W	*40°C 50°Bx*	*1,00* [a]	*1,00* [a]	*1,00* [a]
	60°C 65°Bx	*1,00* [a]	*1,00* [a]	*1,00* [a]
	Average	**1,00 a**	**1,00 a**	**1,00 a**
PTMA	*40°C 50°Bx*	*1,01* [a]	*0,99* [a]	*0,88* [ab]
	60°C 65°Bx	*0,88* [b]	*0,91* [ab]	*0,74* [bc]
	Average	**0,95 b**	**0,95 a**	**0,81 b**
PTB	*40°C 50°Bx*	*0,49* [c]	*0,67* [c]	*0,59* [cdef]
	60°C 65°Bx	*0,38* [d]	*0,48* [ef]	*0,52* [def]
	Average	**0,44 c**	**0,57 c**	**0,56 c**
ODW	*40°C 50°Bx*	*0,39* [d]	*0,81* [b]	*0,61* [cde]
	60°C 65°Bx	*0,31* [e]	*0,64* [cd]	*0,51* [def]
	Average	**0,35 d**	**0,73 b**	**0,56 c**
ODMA	*40°C 50°Bx*	*0,45* [c]	*0,67* [c]	*0,66* [cd]
	60°C 65°Bx	*0,26* [e]	*0,50* [e]	*0,45* [efg]
	Average	**0,35 d**	**0,58 c**	**0,56 c**
ODB	*40°C 50°Bx*	*0,28* [e]	*0, 53* [de]	*0,43* [fg]
	60°C 65°Bx	*0,18* [f]	*0,38* [f]	*0,30* [g]
	Average	**0,23 e**	**0,46 d**	**0,37 d**

* Testing conducted by columns by Duncans's test at the threshold of 5% significance.

3.2. Changes in carrot root color

Color is one of the most important features of the product look, which have a decisive influence on its acceptance by consumers [5]. Statistically significant differences in the color due to the effect of pretreatment with malic acid were determined by the parameter b*. Blanching caused statistically significant differences all the observed parameters with regard to the fresh sample. For osmotic dehydration were measured significantly lower values for brightness (L*). The lowest value (49.03) was measured for blanched and osmotic dehydrated carrot root (ODB). Samples without previous treatment and osmotic dehydration samples resulted in statistically equal values for the parameters a* and b*. Samples treated with malic acid, before and after osmotic dehydration, statistically equal value were determined for the parameters a*, b* and dE*ab. Blanched samples, before and after osmotic dehydration statistically equal values determined for the parameters L* and b*. Results of previous research have found that during osmotic dehydration the color is very approximate fresh fruit [6].

Table 3: Changes in carrot root color depend on pretreatment and osmotic dehydration.*

Treatment	OD	L*	a*	b*	dE*ab
W	*40°C 50°Bx*	*55,97* ^{a}	*18,98* ^{ab}	*42,30* ^{abc}	*11,90* ^{efg}
	60°C 65°Bx	*54,28* ^{ab}	*19,17* ^{ab}	*42,00* ^{abc}	*12,64* ^{defg}
	Average	**55,12 a**	**19,07 a**	**42,15 a**	**12,27 cd**
PTMA	*40°C 50°Bx*	*54,94* ^{ab}	*16,01* ^{bcde}	*38,54* ^{cd}	*14,89* ^{cde}
	60°C 65°Bx	*54,34* ^{ab}	*17,62* ^{abc}	*38,64* ^{cd}	*14,45* ^{cdef}
	Average	**54,64 ab**	**16,81 abc**	**38,59 bc**	**14,67 bc**
PTB	*40°C 50°Bx*	*50,94* ^{def}	*11,58* ^{f}	*32,58* ^{f}	*20,54* ^{a}
	60°C 65°Bx	*50,24* ^{f}	*13,99* ^{cdef}	*36,16* ^{de}	*16,19* ^{bcd}
	Average	**50,59 ef**	**12,79 d**	**34,37 d**	**18,36 a**
ODW	*40°C 50°Bx*	*53,43* ^{abcd}	*18,77* ^{ab}	*43,20* ^{a}	*10,26* ^{g}
	60°C 65°Bx	*51,51* ^{cdef}	*15,56* ^{bcde}	*40,98* ^{abc}	*12,96* ^{defg}
	Average	**52,47 cd**	**17,16 ab**	**42,09 a**	**11,61 d**
ODMA	*40°C 50°Bx*	*49,84* ^{f}	*12,42* ^{ef}	*36,07* ^{de}	*17,63* ^{abc}
	60°C 65°Bx	*53,81* ^{abc}	*16,46* ^{abcd}	*39,83* ^{abcd}	*13,77* ^{defg}
	Average	**51,82 de**	**14,44 cd**	**37,95 bc**	**15,70 b**
ODB	*40°C 50°Bx*	*47,38* ^{g}	*13,31* ^{def}	*33,24* ^{ef}	*18,45* ^{ab}
	60°C 65°Bx	*50,68* ^{ef}	*18,56* ^{ab}	*39,76* ^{abcd}	*11,02* ^{fg}
	Average	**49,03 f**	**15,94 bc**	**36,50 cd**	**14,73 bc**

* Testing conducted by columns by Duncans's test at the threshold of 5% significance.

4. CONCLUSIONS

After osmotic dehydration (3 hours) there was a statistically significant change in the mass, volume and moisture content of carrot roots. Moisture content in reference to the temperature and concentration of the solution, after osmotic dehydration in blanched samples was 66.96% and 50.06%. For samples treated with malic acid measured values was 65.15% and 47.15%, and without any pretreatment 69.40% and 48.96%. The difference in structure between the root xylem and phloem confirm different depending on the force of penetration distance. Measuring the mechanical properties of blanched samples before and after osmotic dehydration measured the highest and statistical significant changes. Measuring the change in color, statistically significant differences were found between fresh and blanched samples. Application of osmotic dehydration, the observed pretreatment was not changed in color for most of the studied parameters. These measured physical properties had a great practical importance in the introduction of new products osmotic dehydrated carrot.

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Original scientific paper

MASS TRANSFER KINETICS DURING OSMOTIC DEHYDRATION OF SOUR CHERRY AND SWEET CHERRY AFTER FREEZING IN SACCHAROSE SOLUTION

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Abstract. *Osmotic dehydration is a process of partial removal of water by submersing fruit in hypertonic solution. It is a pre-treatment for further steps of drying, with main aim of conserving the natural fruit quality by reducing the process temperatures and drying times. Studies have shown that osmotic dehydration improves the product quality in terms of color, flavor and texture.*

The aim of the present study was to investigate the influence of different concentration of saccharose solution (75 %, 60 % and 40 % w/w) on mass transfer kinetics during the osmotic dehydration of sour cherry and sweet cherry. One temperature level of osmotic solution at 25 ºC, for 360 min, was evaluated. The mass ratio of solution to sample during the experiment was 10:1, to avoid dilution and decrease of the driving force during the drying. During the experiment of osmotic dehydration the changes of water loss (WL) and solid gain (SG) depending on the time were monitored, using the simple gravimetrical method in oven at 105 ºC. Increase in saccharose solution concentration resulted in higher water loss and solid gain values through the osmosis period for both sour cherry and sweet cherry, due to increase in the osmotic pressure gradients. In addition, the applicability of Peleg's model to the experimental data is evaluated. Peleg's equation presented good fitting for both sour cherry and sweet cherry water loss experimental data.

Key words*: osmotic dehydration, cherry, saccharose*

1. INTRODUCTION

Due to health-beneficial compounds, food producers aim for final food products with preserved phenolic compounds and other valuable phytochemicals. Fruit drying is process mostly used for preservation of fruits. It is, though, well known that traditional drying methods, such as hot air drying, seriously decrease of nutritive and sensorial quality, damaging mainly the flavor, color, and nutrients of the product. Osmotic dehydration is a pre-treatment for further steps of drying, with main aim of conserving the natural fruit quality by lowering the process temperatures and shortening the drying times. Studies have shown that osmotic dehydration improves the product quality in terms of color, flavor and texture (Pavkov et al., 2011; Babić et al., 2008). Not only does osmotic treatment reduce fruit astringency, but it particularly positively affects its mechanical properties (Babić et al., 2008).

Osmotic dehydration is a process of partial removal of water by submersing fruit in hypertonic solution during which the water and little amounts of natural solutes (such as pigments) diffuse from fruit to the solution and the solute is transferred from the osmotic solution to the fruit tissue in a countercurrent manner. Mass transfer during osmosis depends on operating parameters such as concentration and type of the osmotic solution, temperature and period of process (Khoyi & Hesari, 2007). According to previous research, temperature and concentration of osmotic solution are the most influencing parameters on mass transfer kinetics during the process of osmotic dehydration (Babić et al., 2004). Mathematical equations describing mass transfer during the osmotic drying enable better comprehension of dehydrated material composition and operating parameters. In this regard, many theoretical and empirical models have been employed in literature, whereas empirical ones have been more popular given to their relatively easy application (Turhan et al., 2002).

In this work saccharose solution has been used as osmotic medium for dehydration of sour cherry and sweet cherry. Mass transfer kinetics in terms of water loss and solid gain in different concentrations of osmotic solution, at low temperature (one temperature level of 25 ºC), has been studied. Furthermore, the applicability of Peleg‘s equation, to the experimental data has been evaluated. This model has been widely used in literature for dehydratation processes (Azoubel & Murr, 2004; Khoyi & Hesari, 2007; Park et al., 2002; Palou et al., 1994; Peleg, 1988; Sopade & Kaimur, 1999). However, according to our literature research, application of Peleg’s model on osmotic dehydration of cherry fruits, has not been previously reported.

2. MATERIAL AND METHODS

2.1. Material

Sour cherries, cultivar Nord Star, and sweet cherries wildly grown, harvested at processing maturity, were obtained from research orchard Faculty of Agriculture, Belgrade. They were brought to the Department of Food Technology within 2h after harvest. Over-ripped, damaged and under-ripped fruits were manually removed. The fruits average radius was approximately 8,5 mm for sour cherries and 8 mm for sweet cherries . Fruits considered appropriate for further experiments, were stored in freezer at -18 °C. After removing fruits from freezer, average initial moisture content, gravimetrically determined using an oven at 105°C until constant mass of the samples was achieved, was for sour cherry 83,69 % on a wet basis and for sweet cherry 82,53 % on a wet basis. Analytical grade saccharose was purchased from "Merck". Osmotic solutions were prepared by mixing saccharose with required amount of distilled water to give desired concentration of final solution

2.2. Osmotic dehydration

Prior to osmotic dehydration , pits were removed and mass of the halves of fruits was measured. Fruits were immersed into containers, containing 40%, 60% and 75% mass content of saccharose in solutions. Temperature uniformity (25ºC) during experiment was assured by placing containers in a constant temperature water bath. Each experiment was carried out in triplicate. The data presented in this paper correspond to the average of the three data sets obtained from different containers. In all experiments the mass ratio of solution to sample was 10:1 in order to avoid dilution and decrease of the driving force during the drying. Fruits were removed from the containers at a period of 30, 60, 90, 120, 240 and 360 min, quickly rinsed with distilled water and gently blotted with tissue paper to remove excess solution from the surface. The mass of the fruits was then measured and the moisture content (dry matter) was gravimetrically determined.

Water loss (WL) and solid gain (SG) of the samples were calculated based on their mass and after time "t" of osmotic treatment are defined as in Eqs. (1,2) (Pavkov et al., 2008):

$$WL(\%) = \frac{M_o - M_i}{W_o} \cdot 100\,, \tag{1}$$

$$SG(\%) = \frac{S_i - S_o}{W_o} \cdot 100\,, \tag{2}$$

where M_o is the initial moisture content in fresh fruit (g); M_i is the moisture content at time "t" of osmotic treatment (g); S_0 is the dry matter of fresh fruit (g); S_i is the dry matter after time "t" of osmotic treatment (g); W_0 is the initial mass of fresh fruit before the osmotic treatment (g). The data have been processed using Origin6.0 software.

2.3. Peleg's model

Peleg's model has been widely used to describe sorption and desorption processes in various foods. It has been used for water desorption of sago starch , papaya, apricot, cherry tomato, pear etc (Azoubel & Murr, 2004; Khoyi & Hesari, 2007; Park et al., 2002; Palou et al., 1994; Peleg, 1988; Sopade & Kaimur, 1999). Although Park et al. (2000), have found that other mathematical model better predicts kinetics of the pear osmotic dehydration, according to some authors, Peleg's equation presents the best fitting for water loss and the best adjustment to experimental data (Ganjloo et al., 2012; Azoubel & Murr, 2004; Park et al., 2002). However, no literature data regarding application of this model on cherry fruits osmotic dehydration is available.

This two parameter model describes most of the published curves and is used in this work as Eq. (3) (Khoyi & Hesari, 2007; Corzo & Bracho, 2006; Turhan et al., 2002):

$$M = M_o \pm \frac{t}{k_1 + k_2 t}\,, \tag{3}$$

where M is moisture or solid content (g) at time t (h), M_0 is initial moisture or solid content (g), k_1 is the Peleg rate constant (h g^{-1}) and k_2 is the Peleg capacity constant (g^{-1}). In Equation (3) "±" becomes "–" for dehydration processes (Turhan et al., 2002). The Peleg rate constant k_1 relates to dehydration rate at the very beginning, $t=t_0$ and is inversely proportional to initial rate of dehydration (Corzo & Bracho, 2006):

$$\frac{dM}{dt} = \pm \frac{1}{k_1}\,. \tag{4}$$

The Peleg capacity constant k_2 relates to minimum attainable moisture content, so at time $t \rightarrow \infty$ the Eq. (3) gives the relation between equilibrium moisture content (M_e) and k_2 (Corzo & Bracho, 2006; Turhan et al., 2002):

$$M_e = M_o \pm \frac{1}{k_2}\,. \tag{5}$$

Linearization of Eq. (3) give (Corzo & Bracho, 2006):

$$\frac{t}{M - M_o} = k_1 \pm k_2 t\,. \tag{6}$$

The plotting of Eq. (6) is a straight line, where k_1 is the intercept and k_2 is the slope (Turhan et al., 2002).

3. RESULTS AND DISCUSSION

3.1. Mass transfer kinetics evaluation

The process of osmotic dehydration has been studied in terms of water loss and solid gain. The influences of dehydration time and solution concentration on mass transfer kinetics for sour cherry and sweet cherry are shown in Fig. 1 and Fig. 2. As it might be expected, water loss and solid gain in both cases increased with immersion time. During the first 2 hours, the rates of water loss and solid gain are the highest, and are followed by slower removal (and uptake) in later stages. This finding is consistent with previous research of Pavkov et al. (2008), who have also obtained the highest values for water loss and solid gain in the first 2 hours. Similar results have been reported by Koprivica at al. (2010), who have concluded that osmotic dehydration of apple and carrot in sugar beet molasses is the most intense during the first hour of the process. This trend is due to the large osmotic driving force between fresh fruits' dilute sap and surrounding hypertonic solution at the beginning of the process (Mišljenović et al., 2008). Several research papers have published similar curves for osmotic dehydration of foods (Azoubel & Murr, 2004; Ganjloo et al., 2012; Khoyi & Hesari, 2007; Park et al., 2002). Such an increase in the osmotic pressure gradients with an increase in solution concentration, indicates that by using a higher concentration medium, some benefits such as faster water loss could be achieved (Azoubel & Murr, 2004).

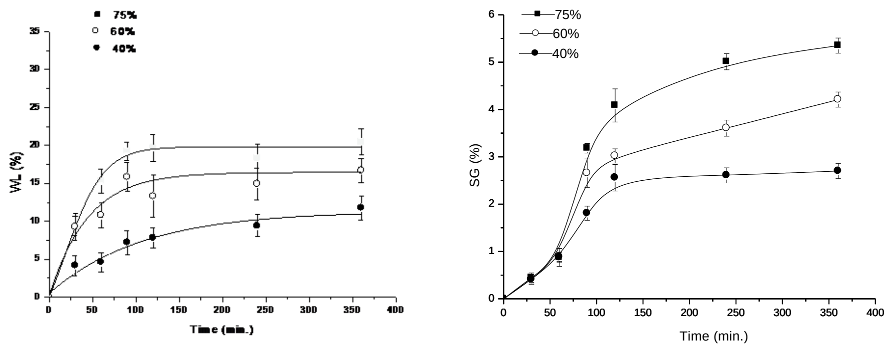

Fig. 1: Sour cherry water loss and solid gain versus time.

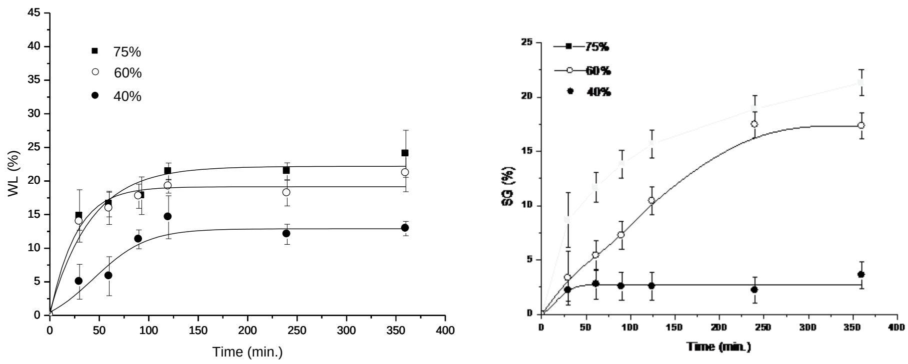

Fig. 2 Sweet cherry water loss and solid gain versus time

3.2. Evaluation of Peleg's parameters

Peleg's equation has been used to depict osmotic dehydration kinetics of sour cherry and sweet cherry. Table 1 and Table 2 present Peleg's parameters under different experimental conditions. The parameter $1/k_1$ describes the initial rate of mass exchange. It can be clearly seen that an inverse relationship between k_1 and solution concentration occurs both for water loss and solid gain. Peleg's parameter k_1 for water loss and solid gain of sour cherry varies from 0.83 ± 0.08 to 1.87 ± 0.09, and from 3.04 ± 0.09 to 5.38 ± 0.03, respectively. Peleg's parameter k_1 for water loss and solid gain of sweet cherry varies from 0.54 ± 0.08 to 2.70 ± 0.09, and from 2.04 ± 0.09 to 5.3 ± 0.3, respectively. The parameter k_2 describes the rate of solid gain (SG) and water loss (WL) at the equilibrium stage of osmotic dehydration process. Peleg's parameter k_2 for water loss and solid gain of sour cherry varies from 0.97 ± 0.08 to 1.49 ± 0.03, and from 2.9 ± 0.1 to 5.89 ± 0.02, respectively. Peleg's parameter k_2 for water loss and solid gain of sweet cherry ranges from 1.40 ± 0.08 to 2.60 ± 0.03, and from 0.9 ± 0.2 to 6.9 ± 0.2, respectively. The k_2 parameter did not exhibit a trend with the increase of concentration for water loss and solid gain. Park et al., (2002) also have not found any relationship between Peleg's equation parameters with the increase of saccharose concentration at constant temperature in the osmotic dehydration of pears.

The criteria which were used for qualification of the goodness of fit (R^2) revealed the adequacy of Peleg's model to predict the values of SG and WL due to the high values of R^2 (Table 1-2).

Table 1 Values of Peleg's equation parameters for water loss and solid gain of sour cherry.

Saccharose concentration (%wb)	Water loss			Solid gain		
	k_1	k_2	R^2	k_1	k_2	R^2
75	0.83 ± 0.08	1.23 ± 0.06	0.970	3.04 ± 0.09	2.9 ± 0.1	0.974
60	1.23 ± 0.05	0.97 ± 0.08	0.989	3.8 ± 0.5	3.9 ± 0.2	0.968
40	1.87 ± 0.09	1.49 ± 0.03	0.967	5.38 ± 0.03	5.89 ± 0.02	0.981

Table 2 Values of Peleg's equation parameters for water loss and solid gain of sweet cherry.

Saccharose concentration (%wb)	Water loss			Solid gain		
	k_1	k_2	R^2	k_1	k_2	R^2
75	0.54 ± 0.08	1.61 ± 0.20	0.970	2.04 ± 0.09	1.6± 0.1	0.974
60	1.05 ± 0.05	1.40 ± 0.08	0.989	3.3 ± 0.5	0.9 ± 0.2	0.978
40	2.70 ± 0.09	2.60 ± 0.03	0.967	5.3 ± 0.3	6.9 ± 0.2	0.981

4. CONCLUSION

The effect of concentration on mass transfer kinetics was investigated in terms of solid gain (SG) and water loss (WL). The rate of water loss and solid gain during the osmotic dehydration of sour cherry and sweet cherry was directly related to the concentration of the solution. During the first 2 hours, the rates of water loss and solid gain were the highest due to larger differences between osmotic pressures of hypertonic solution and fruit tissue. High values of correlation coefficients (R^2) have confirmed that Peleg's equation presents good fitting for both water loss and solid gain experimental data.

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Original scientific paper

COMPARISON OF DIFFERENT BY-PRODUCT SILAGES DERIVED FROM SORGHUM PLANT

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Abstract. *The aim of the study was to investigate the fermentation quality of different by-products derived from the sorghum plant applied in the bio-ethanol industry for sugar extraction. Authors ensiled the whole crop, the sorghum leaves (by-product) and the sorghum seedhead-leaf mix (1:1 fresh weight) determining the nutrient content, fermentation quality and hygienic status of the different silages. It was found that the sorghum leaf and the seedhead-leaf mix could be ensiled efficiently. However, fermentation intensity was significantly lower in the sorghum leaf- and seedhead-leaf mixed silages, than in the whole crop sorghum silage, while lactic acid- and acetic acid ratio were similar. The by-product sorghum silages had higher dry matter content (401 g/kg and 453 g/kg, respectively), as compared to the whole crop sorghum silages (290 g/kg dry matter), limiting the fermentation process and in parallel the harmful bacteria proliferation.*

Key words: *Sorghum, fermentation, silage*

1. INTRODUCTION

The sorghum is a drought-tolerant plant highly adapted to the dry climatic conditions. Waxy leaves, low number of the *stoma* and deep root-system help to survive the hot weather with low precipitation, regenerating after the drought. The sorghum can provide the highest green yield among the different types of forages [1, 2, 3, 4]. The sugar-type sorghum plant has a potential green yield of 50-90 t/ha and 4-9 t/ha sugar yield. The potential green yield, drought-tolerant characteristics and high sugar content are the main reasons to use this plant on arid area of Central-Europe in animal nutrition and bio-ethanol industry for sugar extraction.

The sorghum plant stem enriched in sugar, the leaf and the seed can be considered as by-product from this point of view. Information about the silage quality of the sorghum seed and leaf is limited at the moment.

The aim of the study was to investigate the fermentation quality of different by-products derived from the sorghum whole plant applied in the bio-ethanol industry for sugar extraction. Authors ensiled the whole sorghum plant, the leaves (as by-product) and seedhead-leaf mix (1:1 fresh weight) determining the fermentation process during the anaerobic phase, the fermentation quality and hygienic status of the different silages.

2. MATERIAL AND METHODS

Harvest and chop Harvest was carried out by handwork in 2009 (30th of October). Different parts of the whole plant were separated in the case of 60% of the harvested yield, by hand. The whole plant, stems, the seedheads and the leaves were chopped individually.

Preparation of seedhead-leaf mix Aim was to reach minimum 30% and maximum 50% dry matter content in order to reduce the effluent production and maintain the optimal conditions for packing (minimum 200 kg dry matter/m^3 density) and intensive fermentation process. The composition of the seedhead and leaf mix (1:1 fresh weight) suited to the natural seedhead and leaf ration of the plant in 2009 and was reliable for the large-scale farm harvest.

Ensiling was executed on the 30th of October 2009 on the pilot farm of the Department of Nutrition, at Szent István University, in Hungary. The small-scale silage trial has been finished on the 11th of December in 2009, after 40 days fermentation. The fresh, whole crop sorghum, the sorghum leaves and the sorghum seedhead-leaf mixes were packed by hand into 30 model mini silos (n=5). Ensiling was carried out into a special model silo system (airtight sealing, special air-valves for gas emission, volume: 0.041 m^3, applied density: 180-200 kg dry matter/m^3). Model silo were stored in room temperature.

Applied treatments were the followings:

1. WCS - chopped whole crop sorghum plant (10 model silos);
2. SSL - chopped mix of sorghum seedhead and leaf, in ratio of 1:1 fresh weight (10 model silos) and
3. SL - soghum leaf (10 model silos).

The authors applied 5 model silos, as repetition in each treatment for each sampling.

Sampling Two samplings were carried out during the trial, on the 7th and 40th day of fermentation (n=5). Crude nutrients, fiber fractions (NDF Neutral Detergent Fiber, ADF Acid Detergent Fiber, ADL Acid Detergent Lignin), total sugar content (fresh material and silages), pH, lactic- and volatile fatty acid, ethanol, ammonia content and microbial status (moulds and aerobic bacteria) were measured (silages, 3 treatments, n=5) according to the Hungarian National Standards.

Statistical analyses The chemical compositional data of the fresh material and the silage samples (n=5), fermentation profile and microbial counts (except mould counts) of the silage samples (n=5) were analyzed for their statistical significance with SPSS (version PASW Statistics 18). All microbial counts were log10 transformed to obtain log-normal distributed data. Chemical composition, fermentation profile and microbial status were analyzed for their statistical significance by ANOVA. Significant differences between variances were identified by the P-values of ANOVA, and the effects were considered significant at $p \leq 0.05$. When calculated values of F were non-significant (equal variances), Student t-test for equality of means was used ($p \leq 0.05$), when calculated values of F were significant (non-equal variances), Welch's t test ($p \leq 0.05$) was used to interpret any significant differences among the mean values. Mould counts were analyzed for their statistical significance by the Wilcoxon test.

3. RESULTS AND DISCUSSION

3.1. Density

The applied weight of the different fresh base material were similar (WCS 2.2 kg/model silo; SSL 1.6 kg/model silo, SL 1.4 kg/model silo). The authors adjusted the packed fresh weight to the give and fixed volume according to the measured dry matter content in order to reach similar dry matter density in the model silos (WCS 190 kg dry matter/m^3; SSL 192 kg dry matter/m^3; SL 195 kg dry matter/m^3). The authors assumed that the consolidation in the case of SL treatment was difficult, so additional water (minimum 100 kg/t fresh material) recommended in large scale farm work. Compressibility of WCS and SSL was convenient, so additional water is not needed.

3.2. Nutrient content

Crude nutrient composition of the fresh whole crop sorghum (WCSO), the fresh sorghum seedhead-leaf mix (SSL) and the fresh sorghum leaf (SL) is given in Table 1.

Table 1: Crude nutrient composition of the fresh whole crop sorghum (WCS), the fresh sorghum seedhead-leaf mix (SSL) and the fresh sorghum leaf (SL) (harvest 2009).

Fresh		**WCS**	**SSL**	**SL**
Dry matter	g/kg	278	394	490
Crude protein	g/kg dry matter	55	47	52
Crude fat	g/kg dry matter	31	30	22
Crude fiber	g/kg dry matter	327	349	338
Crude ash	g/kg dry matter	63	52	54
N-free extract	g/kg dry matter	524	522	536
NDF	g/kg dry matter	695	750	752
ADF	g/kg dry matter	375	408	396
ADL	g/kg dry matter	41	43	46
Hemicellulose	g/kg dry matter	320	342	356
Cellulose	g/kg dry matter	334	365	350
Aerobic bacteria	log10 CFU/g fresh	8.2	8.0	7.2
Mould and yeast	log10 CFU/g fresh	7.1	7.0	6.1

Crude nutrient composition of the whole crop sorghum silage (WCS), the sorghum seedhead-leaf mixed silage (SSL) and the sorghum leaf silage (SL) on the 40^{th} day of fermentation are given in Table 2.

Table 2 Nutrient content of the whole crop sorghum silage (WCS), the sorghum seedhead-leaf mixed silage (SSL) and the sorghum leaf silage (SL) on the 40th day of fermentation (2009, n=5)*.

40th day of anaerobic phase			WCS	SSL	SL
Dry matter	g/kg	mean	292a	401b	453b
		standard deviation	7.1	5.8	15.2
Crude protein	g/kg dry matter	mean	52a	54a	45b
		standard deviation	4.7	3.2	2.8
Crude fat	g/kg dry matter	mean	15a	18a	25b
		standard deviation	0.9	0.5	3.1
Crude fiber	g/kg dry matter	mean	304a	330b	340c
		standard deviation	11.5	3.3	2.9
Crude ash	g/kg dry matter	mean	52a	57a	57a
		standard deviation	4.9	3.1	4.5
N-free extract	g/kg dry matter	mean	577a	541b	532b
		standard deviation	6.7	4.9	8.2
NDF	g/kg dry matter	mean	610a	745b	740b
		standard deviation	21.5	9.3	3.4
ADF	g/kg dry matter	mean	342a	416b	409b
		standard deviation	10.1	7.6	8.7
ADL	g/kg dry matter	mean	53a	57a	41b
		standard deviation	2.5	1.9	2.1
Hemicellulose	g/kg dry matter	mean	238a	316b	321b
		standard deviation	4.3	5.8	7.9
Cellulose	g/kg dry matter	mean	289a	355b	367b
		standard deviation	9.1	6.8	5.9

*Different letters show significant difference $p \leq 0.05$.

The dry matter content significantly differred among the treatments: SSL and SL had higher dry matter content as compared to the whole crop silage (WCS). The SSL and SL silages contained significantly higher crude fiber-, NDF- and ADF-content based on higher hemicellulose and cellulose content. The SL had the lowest lignin (ADL) content.

3.3. Fermentation

Fermentation profile and microbial status of the whole crop sorghum silage (WCS), the sorghum seedhead-leaf mixed silage (SSL) and the sorghum leaf silage (SL) on the 7th and 40th day of anaerobic phase (fermentation) are shown in Table 3.

Table 3 Fermentation profile and microbial status of the whole crop sorghum silage (WCS), the sorghum seedhead-leaf mixed silage (SSL) and the sorghum leaf silage (SL) on the 7th and 40th day of anaerobic phase (2009, n=5)*.

			7th day, n=5			**40th day, n=5**		
Parameter	**Measuring unitss**		**WCS**	**SSL**	**SL**	**WCS**	**SSL**	**SL**
pH	-	mean	4.3a	5.7b	6.3c	3.7a	5.0b	5.6b
		standard dev.	0.1	0.1	0.5	0.3	0.4	0.5
Lactic acid	g/kg DM	mean	20.6a	7.6b	3.9b	106.7a	14.3b	9.42b
		standard dev.	1.3	2.0	3.5	1.8	4.2	3.17
	% total acid		58.4	67.3	59.9	74.9	72.5	73.35
Acetic acid	g/kg DM	mean	14.7a	3.6b	2.3b	14.5a	5.3b	3.02b
		standard dev.	1.3	0.2	1.3	0.9	0.	1.36
	% total acid		41.6	32.7	40.1	29.2	27.4	23.55
Propionic acid	g/kg DM	mean	0.0a	0.0a	0.0	0.0a	0.0a	0.13b
		standard dev.	0.0	0.0	0.0	0.0	0.0	0.01
	% total acid		0.0	0.0	0.0	0.0	0.0	1.08
Butyric acid	g/kg DM	mean	0.0a	0.0a	0.0a	0.0a	0.0a	0.25b
		standard dev.	0.0	0.0	0.0	0.0	0.0	0.07
	% total acid		0.0	0.0	0.0	0.0	0.0	2.02
Ethanol	g/kg DM	mean	14.1a	6.7b	5.4b	22.2a	7.7b	11.4b
		standard dev.	2.6	0.9	3.3	1.8	0.3	3.7
Volatile acids	g/kg DM	mean	14.7a	3.6b	2.3b	14.5a	5.3b	3.4b
		standard dev.	1.3	0.2	1.3	0.9	0.4	1.4
Organic acids	g/kg DM	mean	35.2a	11.2b	6.1c	121.2a	19.6b	12.8b
		standard dev.	1.8	2.0	4.6	2.6	4.1	4.1
Fermentation products	g/kg DM	mean	49.3a	17.8b	11.5b	143.4a	27.3b	24.2b
		standard dev.	3.2	2.4	5.6	0.8	4.4	4.9
Lactic/acetic acid ration	g/g	mean	1.4a	2.1a	1.6a	7.4a	2.7b	3.2b
		standard dev.	0.2	0.6	0.7	0.1	0.8	1.0
Ammonia N total N	%	mean	13.0a	14.6a	11.0a	21.0a	25.0a	20.0
		standard dev.	1.1	0.3	1.0	3.4	2.6	2.8
Aerobic bacteria	log10 CFU/g	mean	5.4a	8.1b	8.5b	6.0a	8.7b	9.0b
		standard dev.	0.1	0.1	0.4	0.6	0.5	0.9
Mould and yeast	log10 CFU/g	mean	2.3a	3.4b	4.3b	3.0a	4.4b	5.1b
		standard dev.	0.3	1.1	1.8	0.2	0.9	1.9

*Different letters show significant difference p≤0,05 DM - dry matter.

The authors found that the acetic acid content and ratio were relatively high in each silages on the 7th day of fermentation (WCO 41.6%; SSL 32.7%; SL 40.1%). Additionally, high ethanol concentration was found on the 7th day in each treatment. There were significant differences between the treatments. WCS silage had the most intensive fermentation in that stage (7th day) based on the lowest pH and highest fermentation product concentration compared to SSL and SL ($p \leq 0,05$).

The authors have found more intensive fermentation in the case of WSC as compared to SSL and SL on the 40th day of fermentation, as well. Fermentation profile of WSC significantly differed (pH, lactic acid content, acetic acid content, ethanol, volatile acids, organic acids, total fermentation products) from SSL and SL, while character of SSL and SL was very similar to each other on the 40th day of fermentation. Significantly higher lactic acid content (but similar lactic acid ration) was found in WCS compared to SSL and SL on the 40th day. However, WCS contained significantly higher ethanol and acetic acid content, than SSL or SL. The presumable reason of lower fermentation intensity (higher pH, lower lactic-, acetic-, organic acid and ethanol content), but very similar acid ration in SSL and SL compared to WCS, is the significantly higher dry matter content in SSL and SL (401 g/kg and 453 g/kg, respectively). High dry matter content inhibited the fermentation process and in parallel the harmful acetic acid producing bacteria proliferation. The high dry matter content had positive and negative effect in the same time on the fermentation profile of SSL and SL, as compared to WCS.

Fermentation profile (pH and organic acid concentration) of the SL treatment was especially poor, therefore that type of silage can be unstable during long-term storage. In order to prevent the deterioration and secondary fermentation, additional water application during packing is recommended to increase moisture content and fermentation intensity in the silage.

Fermentation process was slow and intensity was rather low in SSL and SL (high pH and low lactic- and organic acid content on the 7th and 40th day of fermentation), therefore additional homofermentative lactic acid bacterial inoculation is recommended in the future in order to increase beneficial microflora and lactic acid fermentation.

Microbial composition of WSC significantly differed from SSL and SL, while character of SSL and SL was very similar to each other on the 40th day of fermentation. WSC contained significantly less aerobic bacteria, mould and yeast than SSL and SL. Anaerobic fermentation process reduced the aerobic bacteria proliferation in WCS, but there was not found significant difference between the fresh material and the silage microbial composition in SSL and SL. These results showed higher porosity in SSL and SL, compared to WCS. Mould count significantly decreased in each treatment during the anaerobic process.

4. CONCLUSIONS

The authors have found that the sorghum seedhead-leaf mix (1:1 fresh weight) and the sorghum leaf can be ensiled efficiently. Authors summarized, that SSL and SL silages can be potential feedstuffs for dairy cattle (heifers, dry cows) and beef cattle according to the measured nutrient content. Fermentation intensity and profile of the SSL and SL was significantly different, as compared to the whole crop sorghum silage (WCS). The reason of the harmful effect was the high dry matter content (401 g/kg and 453 g/kg, respectively). Fermentation profile of the sorghum leaf silage treatment was especially poor and consolidation was extremely difficult, therefore additional water application (minimum 100 kg water/ton fresh material) during packing is recommended to increase moisture content and fermentation intensity in the silage. High pH, low lactic- and organic acid content were found in the seedhead-leaf mixed silage (1:1 frresh weight) and sorghum leaf silage, therefore additional homofermentative lactic acid bacterial inoculation is recommended in the future in order to increase beneficial microflora proliferation and lactic acid fermentation. Intensive lactic acid fermentation provides anaerobic stability of the silage during long-term storage.

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Expert paper

LIGNOCELLULOSE FIBRES AND RESISTANT STARCH OF MAIZE HYBRIDS

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Abstract. *The objective of this study was to investigate and compare ZP maize hybrids of a different genetic background for lignocelluloses fibres and resistant starch. The results showed that the NDF, ADF, ADL, hemicelluloses and cellulose contents in the whole maize plant of the observed different ZP hybrids varied from 41.7% to 50.0%, 19.3% to 21.3%, 2.9% to 3.5%, 22.4 to 28.7% and 15.9 to 17.9%, respectively. The hybrid ZP 544 had the highest content of NDF and ADF in the plant without the ear and the lowest dry matter digestibility of (45.1%). Starch, protein and oil contents of kernel ranged from 67.9 to 73.0%, 8.5 to 12.7% and 4.7 to 6.4%, respectively. The amylase content, being characteristic for normal, i.e. waxy maize starches, ranged from 26.0 to 1.0%. The resistant starch content was very low (0.62–1.61%) in the samples of selected ZP maize hybrids.*

Key words: *maize hybrids, lignocelluloses fibres, resistant starch*

1. INTRODUCTION

Maize is one of the most important crops, and as such, one of the most significant naturally renewable carbohydrate raw materials. In Serbia, maize is a traditionally mostly grown crop [1]. The predominant maize type grown in the world and our country is dent. Dent types vary widely in their compositions. The main aim of modern maize breeding is the development of high yielding hybrids tolerant to drought and pests. Little attention has been paid to the nutritional value of maize as a food and feed raw material. However, advances have been made by breeders within this area as well, resulting in maize hybrids with specific traits [2, 3].

Cell walls are the most abundant reservoir of carbohydrate in nature their resistance to degradation has been fine tuned throughout evaluation making them difficult to access and convert into biological energy. The cell wall of maize is almost completely composed polysaccharides, which form cellulose and hemicelluloses, and a complex mixture of polymers called lignin [4]. Research has revealed that plant genetics can affect the quality and digestibility of whole plant maize silage [5]. Limited research has focused on laboratory analyses, which are associated with differences in lignocelluloses fibres content and digestibility of maize forages. Percentages of crude fibre and fibre constituents (ADF, NDF and ADL) of silage maize were associated with digestibility [6]. Previously published our results point out to a great importance and necessity of the characterisation of the released maize hybrids for both, the determination of purposes of certain hybrids and the development of new high yield potential hybrids for silage [7, 8, 9, 10, 11, 12].

Typically, maize contains about 70% of starch in the kernel [13]. Starch is a carbohydrate component that has the greatest influence on the maize grain yield. As starch makes two thirds of a maize grain dry matter, it is therefore its the most important economic component [14]. Compositions of maize starch vary depending on genotypes. Normal maize starch contains about 25-30% amylose and 70-75% amylopectin, while waxy starch mainly consisits of amylopectin. Resistant starch (RS) is the portion of starch that is not digested in small intestine, but is fermented by micro flora in the colon [15]. RS provides more health benefits than dietary fibres. Furthermore, RS has been reported to have potential as a unique ingredient that can yield high-quality foods.

The objective of this study was to observe the content of lignocelluloses fibres of ZP maize hybrids of a different genetic background and to determine the relationship of these parameters, as well as, their effects on the digestibility of maize forage dry matter. In addition, the kernel chemical composition (starch, protein and oil contents), resistant starch and amylase and amylopectin contents were determined in samples of ZP maize hybrids of different maturity groups, various genetic bases and utilisation purposes.

2. MATERIAL AND METHODS

The hybrids of the FAO maturity groups 300-800 (ZP 341, ZP 544, ZP 737, ZP 750, ZP 74b, ZP 360, ZP 434, ZP 578, ZP 611k, ZP 633, ZP 684, ZP 704wx, ZP 808, ZP Rumenka) were used in this study. The two-replicate trail was set up according to the randomised complete-block design in the experimental plot of the Maize Research Institute, Zemun Polje. The experimental plot size amounted to $21m^2$, while sowing density was 50,000 plants per hectare. Plants of each replicate were harvested in the full waxy maturity stage from the area of $7m^2$ (two inner rows). Samples of whole maize plants were chopped and dried and then ground in the mill with 1-mm sieves. The modified Van Soest detergent method was applied to determine lignocellulose fibres (NDF - neutral detergent fibres, ADF - acid detergent fibres, ADL - acid detergent lignin) [16]. *In vitro* digestibility of the whole maize plant was done by the Aufréré method [17]. The maize samples for the determination of the kernel chemical composition were harvested in full i.e. technological maturity stage. The starch content was determined by the Ewers polarimetric method [18]. The protein content was estimated as the total nitrogen by the Kjeldahl method multiplied by 6.25 [19]. The lipid concentration was determined according to the Soxhlet method [20]. The amylase content was determined by a rapid colorimetric method [21]. The RS content was determined according to the enzymatic gravimetric method [22].

Data reported for tested parameters of the ZP hybrids were assessed by the analysis of variance (ANOVA) and the LSD multiple test was used for any significant differences at the $P<0.05$ level between the means. All the analyses were conducted using the statistical software package STATISTICA 8.1. (StatSoft Inc. USA).

3. RESULTS AND DISCUSSION

3.1. Lignocellulose fibres and *in vitro* digestibility of ZP maize hybrids

The contents of lignocelluloses fibres and digestibility of the whole maize plant, stover and ear are presented in Tables 1, 2, 3 and 4. The results show that the NDF, ADF, ADL, hemicelluloses, cellulose contents in the whole maize plant of the observed ZP maize hybrids varied from 41.74 (ZP 544) to 49.95% (ZP 750), 19.34 (ZP 544) to 21.25% (ZP 750), 2.88 (ZP 341) to 3.53% (ZP 737), 22.14 (ZP 544) to 28.70% (ZP 750) and 15.93 (ZP 544) to 17.94% (ZP 750), respectively. Among the tested hybrids, the hybrid ZP 750 had the highest NDF (49.95%), ADF (21.25%), hemicelluloses (28.70%) and cellulose (17.94%) and the lowest dry matter digestibility (56.43%). However, the hybrid ZP 544 had had the highest dry matter digestibility (68.17%) and the lowest NDF (41.74%), ADF (19.34%), hemicelluloses (22.41%) and cellulose (15.93%) content of the whole plant (Table 1 and 4). The differences in the contents of ADL and cellulose in the whole plant among observed maize hybrids were not significant.

Table 1: Whole plant lignocellulose fibres content of maize hybrids.

Hybrid	NDF (%)	ADF (%)	ADL (%)	Hemicellulose (%)	Cellulose (%)
ZP 341	43.56^{c}	20.33^{a}	2.88	23.24^{c}	17.45
ZP 544	41.74^{d}	19.34^{b}	3.40	22.41^{c}	15.93
ZP 737	46.29^{b}	20.69^{a}	3.53	25.61^{b}	17.16
ZP 750	49.95^{a}	21.25^{a}	3.31	28.70^{a}	17.94
$LSD_{0.05}$	069	0.97	-	0.87	-

The data in Table 2 show that the NDF, ADF, ADL, hemicelluloses and cellulose of the stover of the observed maize hybrids varied from 61.91(ZP 750) to 69.41% (ZP 544), 30.77 (ZP 750) to 37.37% (ZP 544), 4.64 (ZP 750) to 6.56% (ZP 544), 31.14 (ZP 750) to 32.27 (ZP 737) and 26.13 (ZP 750) to 30.81% (ZP 544), respectively.

Table 2: Stover lignocellulose fibres content of maize hybrids.

Hybrid	NDF (%)	ADF (%)	ADL (%)	Hemicellulose (%)	Cellulose (%)
ZP 341	64.94^{b}	33.60^{b}	4.95	31.34^{bc}	28.66
ZP 544	69.41^{a}	37.37^{a}	6.56	32.04^{ab}	30.81
ZP 737	65.33^{b}	33.06^{b}	5.68	32.27^{a}	27.38
ZP 750	61.91^{b}	30.77^{b}	4.64	31.14^{c}	26.13
$LSD_{0.05}$	3.80	3.24	-	0.73	-

The hybrid ZP 544 had the highest content of NDF, ADF, ADL and cellulose and the lowest dry matter digestibility (45.12%), while the hybrid ZP 750 had the lowest content of NDF, ADF, ADL, hemicelluloses and cellulose and the highest dry matter digestibility (53.44%) in the stover (Table 2 and 4). The differences in the content of ADL and cellulose in stover among observed maize hybrids were not significant, as well as in the whole plant.

Table 3 shows that the NDF, ADF, ADL, hemicelluloses and cellulose content of the ear ranged from 23.28 (ZP 737) to 25.56% (ZP 341), 8.29 (ZP 737) to 10.02% (ZP 341), 1.88 (ZP 737) to 2.35% (ZP 750), 14.55 (ZP 341) to 15.46% (ZP 544) and 6.42 (ZP 737) to 9.07% (ZP 341), respectively. The hybrid ZP 341 had the highest content of NDF, ADF, and cellulose and the lowest dry matter digestibility (70.41%), while the hybrid ZP 737 had the lowest content of NDF, ADF, ADL and cellulose the highest dry matter digestibility (81.21%) of the ear for investigated hybrids (Table 3 and 4).

Table 3: Ear lignocellulose fibres content of maize hybrids.

Hybrid	NDF (%)	ADF (%)	ADL (%)	Hemicellulose (%)	Cellulose (%)
ZP 341	25.56	10.02a	1.94	14.55	9.07a
ZP 544	25.02	9.56ab	1.99	15.46	7.57ab
ZP 737	23.28	8.29b	1.88	14.99	6.42b
ZP 750	24.32	9.62ab	2.35	14.71	7.27b
$LSD_{0.05}$	-	1.57	-	-	1.63

Table 4: Digestibility of maize hybrids.

Hybrid	Dry matter digestibility (%)		
	Whole plant	Stover	Ear
ZP 341	67.16^a	49.14^b	70.41^c
ZP 544	68.17^a	45.12^c	71.85^c
ZP 737	63.84^b	48.95^b	81.21^a
ZP 750	56.43^c	53.44^a	78.78^b
$LSD_{0.05}$	1.32	2.08	2.26

The results also show that the differences in the content of NDF, ADL and hemicellulose in ears among observed maize hybrids were not significant. The digestibility of the whole plant, stover and ear dry matter among tested ZP maize hybrid ranged from 56.43 (ZP 750) to 68.17% (ZP 544), 45.12 (ZP 544) to 53.44% (ZP 750) and from 70.41 (ZP 341) to 81.21% (ZP 737), respectively (Table 4). The hybrid ZP 544 had the highest whole plant dry matter digestibility despite the lowest and lower dry matter digestibility of stover and ears, respectively. The participation of the ear dry matter in the yield of the hybrids ZP 544 and ZP 750 were 62.93 and 51.66%, respectively. The differences in the participation of the ear dry matter in the yield (11.27%) affected the differences in whole plant dry matter digestibility of these two hybrids. The correlation dependence between the content of the lignocellulose fibres and the dry matter digestibility of the whole maize plant, stover and ear was determined (Table 5, 6 and 7).

A very significant negative correlation was established between digestibility of the whole maize hybrid plants and NDF, ADF and hemicelluloses content (r=-0.97, r=-0.84, r=-0.98, respectively) and a significant negative correlation between the cellulose content and the dry matter digestibility (r=-0.78) (Table 5). Furthermore, a highly significant negative correlation between digestibility of maize hybrids stover and NDF, ADF, ADL and cellulose contents (r=-0.96, r=-0.94, r=-0.84 and r=-0.87, respectively) and a significant negative correlation between the hemicellulose content and the dry matter stover digestibility (r=-0.71) (Table 6) were established. However, a significant negative correlation was determined between the ear digestibility and NDF, ADF and cellulose ear content of ZP maize hybrids (r=-0.70, r=-0.78, r=-0.76, respectively) (Table 7). Similar results were reported by Terzic *et al*. (2012) [10], Frey *et al.* (2004) [23] and Radosavljević *et al*., 2012 [24]. Frey *et al.* (2004) evaluated the forage yield and quality of the Wisconsin Quality Synthetic and related population developed by the University of Wisconsin Maize Breeding Program for agronomic and nutritional attributes. Their results indicated that it is feasible to develop silage maize germplasm with both high whole-plant yield and excellent nutritional quality [23]. Firdous and Gilani (2002) [25] ascertained that NDF, ADF, cellulose and hemicelluloses contents were significantly negatively correlated with *in vitro* dry matter digestibility of whole plant in maize hybrids.

Table 5: Correlation dependence between whole plant digestibility and lignocellulose fibres of ZP maize hybrids.

	NDF	ADF	ADL	Hemicellulose	Cellulose
ADF	0.92**				
ADL	0.20	0.06			
Hemicellulose	0.99**	0.87**	0.24		
Cellulose	0.84**	0.79*	-0.03	0.83**	
Dry matter digestibility	-0.97**	-0.84**	-0.19	-0.98**	-0.78*

Table 6: Correlation dependence between stover digestibility and lignocellulose fibres of ZP maize hybrids.

	NDF	ADF	ADL	Hemicellulose	Cellulose
ADF	0.99**				
ADL	0.84**	0.80*			
Hemicellulose	0.70**	0.59	0.74*		
Cellulose	0.94**	0.97**	0.62	0.45	
Dry matter digestibility	-0.96**	-0.94**	-0.84**	-0.71*	-0.87**

Table 7: Correlation dependence between ear digestibility and lignocellulose fibres of ZP maize hybrids.

	NDF	ADF	ADL	Hemicellulose	Cellulose
ADF	0.80*				
ADL	0.22	0.12			
Hemicellulose	0.42	-0.21	0.18		
Cellulose	0.65	0.89**	-0.34	-0.28	
Dry matter digestibility	-0.70*	-0.78*	0.06	0.03	-0.76*

3.2. Kernel chemical composition, resistant starch and amylase and amylopectin contents of ZP maize hybrids

Among the different types of maize, the chemical composition of the dent maize kernel was studied the most in the past [12]. However, the objective of this study was to observe kernel chemical composition (starch, protein and oil contents), resistant starch, amylase and amylopectin contents in samples of ZP maize hybrids of different maturity groups, various genetic bases and utilisation purposes. The results are shown in Table 8 and Figure 1. Chemical compositions widely differed among ten selected ZP maize hybrids. The results show that starch, protein and oil ranged from 67.87 (ZP Rumenka) to 72.99% (ZP 558), 8.50 (ZP 360) to 12.65% (ZP 611k) and 4.67 (ZP704wx) to 6.38% (ZP Rumenka), respectively. Moreover, results gained in this study are in agreement with ones previously published by Watson, 2003 [26], Milašinović *et al*., 2007 [13], Srichuwong *et al*., 2010 [27], Semenčenko *et al*., 2012 [28].

Table 8: Kernel chemical composition of maize hybrids.

Hybrid	Starch (%)	Protein (%)	Oil (%)
ZP 74b	70.69^{b}	9.58^{d}	4.77^{ef}
ZP 360	72.53^{a}	8.50^{c}	5.06^{c}
ZP 434	69.02^{c}	9.42^{de}	5.87^{b}
ZP 578	72.99^{a}	8.64^{g}	5.08^{c}
ZP 611k	68.16^{cd}	12.65^{a}	4.84^{de}
ZP 633	72.81^{a}	9.94^{c}	5.06^{c}
ZP 684	70.52^{b}	8.84^{f}	4.82^{ef}
ZP 704wx	71.19^{b}	9.38^{e}	4.67^{f}
ZP 808	72.76^{a}	8.99^{f}	4.97^{cd}
ZP Rumenka	67.87^{d}	11.13^{b}	6.38^{a}
$LSD_{0.05}$	1.00	0.17	0.16

Fig. 1: Amylose and Resistant Starch Content of Maize Hybrids.

Starch is the most important carbohydrate and constitutional part of the maize kernel, which is the major source of the commercial starch production. The amylose content in the starches isolated from ten ZP maize hybrids was characteristic for normal and waxy maize starches. The highest content of amylase was obtained in the starch isolated from ZP 434 (26.0%). The isolated waxy type starch had the lowest value of the amylase content (1%). The RS content in native starch of different ZP maize hybrids (Figure 1) was very low and ranged from 0.62 (ZP 704wx) to 1.61% (ZP 808) [29]. On the basis of the results these authors concluded, the selected dent maize ZP hybrids can be used in wet-milling for production of normal maize starch which may be further modified physically, chemically or enzymatically to meet specific needs and applications.

4. CONCLUSIONS

The results obtained in this study show that the NDF, ADF, ADL, hemicelluloses, cellulose contents in the whole maize plant of the observed different ZP maize hybrids varied from 41.74 (ZP 544) to 49.95% (ZP 750), 19.34 (ZP 544) to 21.25% (ZP 750), 2.88 (ZP 341) to 3.53% (ZP 737), 22.14 (ZP 544) to 28.70% (ZP 750) and from 15.93 (ZP 544) to 17.94% (ZP 750), respectively. Furthermore, the data show that the NDF, ADF, ADL, hemicelluloses and cellulose of stover of the observed maize hybrids varied from 61.91(ZP 750) to 69.41% (ZP 544), 30.77 (ZP 750) to 37.37% (ZP 544), 4.64 (ZP 750) to 6.56% (ZP 544), 31.14 (ZP 750) to 32.27 (Z|P 737) and from 26.13 (ZP 750) to 30.81% (ZP 544), respectively. The NDF, ADF, ADL, hemicelluloses and cellulose content of the ear ranged from 23.28 (ZP 737) to 25.56% (ZP 341), 8.29 (ZP 737) to 10.02% (ZP 341), 1.88 (ZP 737) to 2.35% (ZP 750), 14.55 (ZP 341) to 15.46% (ZP 544) and from 6.42 (ZP 737) to 9.07% (ZP 341), respectively.

Kernel chemical compositions widely differed among ten selected ZP maize hybrids. The results show that starch, protein and oil contents ranged from 67.87 (ZP Rumenka) to 72.99% (ZP 558), 8.50 (ZP 360) to 12.65% (ZP 611k) and 4.67 (ZP704wx) to 6.38% (ZP Rumenka), respectively. The amylose content in starches isolated from ten ZP maize hybrids was characteristic for both types of maize starches, normal and waxy. The RS content was very low in the samples of selected ZP maize hybrids.

This range of lignocelluloses fibres contents (whole plant, stover, ear) and kernel chemical composition of observed ZP maize hybrids provides diverse possibilities in hybrid selection for a certain purpose and their uses in highly-valuable maize-based food and feed products.

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First communication

LYOPHILISATION TECHNOLOGY FOR ISOLATION OF NATURAL SUBSTANCES

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Abstract. *The natural components (anthocyanins) of plant origin in order to therapeutically properties have own advantages in a compare with the synthetic chemistry. With regard to general isolation of these components (secondary metabolites of plants, animals and other organisms) the distillation and extraction methods are used. The method of freeze drying is totally different against distillation or extraction technologies. The aim of research and development is the optimization of anthocyanin lyophilization process from acetone extracts of the Northern high bush blueberry (Vaccinium corymbosum L.) fruits. The acetate extracts were supplied in a frozen condition. The solvent - acetone was vacuum-evaporated after extraction from all samples. The device GEA Lyophil SMART LYO 2 from the German producer GEA was used for the lyophilization. The work consists of two parts: optimally diluted samples by purified water after defrosting and optimization of the lyophilization program in a way to achieve the final product in the form of a dry powder at the end of the process. The basic research in its various stages of this process confirmed that by the method of freeze-drying can be isolated natural substances (anthocyanins) after extraction from plant material with their stabilization and their biological activity.*

Key words: *anthocyanins, blueberry, extract, fruits, lyophilization*

1. INTRODUCTION

Within the general separation of natural compounds (secondary metabolites of plants, animals and other organisms) distillation methods are used (hydro distillation or water vapour), which resulted in the extraction of volatile oils and extracts, where we get liquid and dry extracts. In both methods are used different types of solvents and higher temperature, which directly affects the stability and frequent breakdown of some sensitive natural components. In regard to this fact, lyophilisation is suitable to use for an isolation of special types of natural substances.

Freeze-drying, also known as lyophilisation or cry desiccation, is a dehydration process typically used to preserve a perishable material or make the product, natural substances, with a minimize of the oxidation effects and other degradation processes and finally more convenient for transport. Freeze-drying works by freezing the material and then reducing the surrounding pressure to allow the frozen water in the material to sublimate directly from the solid phase to the gas phase [1, 4].

The aim of research studies were to use and optimisation the lyophilisation technology, as a fundamental procedure, for processing acetone extracts of Northern high bush blueberry (*Vaccinium corymbosum* L.) fruits and isolation of pure anthocyanins.

Anthocyanins are water-soluble vacuolar pigments that may appear red, purple, or blue depending on the pH medium. These natural components occur in all tissues of higher plants, including leaves, stems, roots, flowers, and fruits. Generally they have the considerable preventive and therapeutic effects in relation to different diseases: anti-inflammation, antimicrobial, anti-tumor, anti-mutagenic and anti-oxidant pharmacological properties and a strong biological function.

In regard to the aim of our experimental work - the lyophilisation programs were tested for the anthocyanin extracts. These lyophilisation processes are gradually optimized so that the result of lyophilisation was a perfect dry lyophilized powder.

2. MATERIAL AND METHODS

The plant fruits of the bush blueberry (*Vaccinium corymbosum* L.) for the isolation of anthocyanins were collected from a large-scale cultivation of a special crop in the Krivá region. The locality is situated in North part of Slovakia, at altitude: 634 m above sea level, average temperature during the year is 6^{o} C and precipitation is 895 mm. The soil is very acidic with pH up to 4.2.

1000 g of fresh plant material was macerated in the excess of acetone volume from 3 to 5 times . The filtrate was separated by vacuum aspirator and transferred to a separator funnel and mixed with a double volume of chloroform and shaken several times. The solution was stored in a refrigerator overnight at 4° C. The aqueous phase was separated in the boiling flask. Acetone and chloroform additives were evaporated in a vacuum evaporator at 38° C. Extracts of fruits were supplied frozen in a content of about 400 ml.

Lyophilisation of anthocyanin extracts was carried out by the equipment GEA Lyophil SMART LYO SL2. This new equipment is localised at the Research and Development Department, Medicproduct, Co., Lipany, Slovakia. The liquid material (4 ml) was filled on an automatic filling line (Flexicom Watson Marlow FPC 50W, Denmark) into vials (size 10R, diameter 24 mm, height 45 mm). Vials were closed after filling, with rubber stoppers (type no. V9355) to the position for lyophilisation and were loaded into the lyophilisator. After lyophilisation the stoppers were closed and capped on the line (edging aluminium stopper type no. 25345). The prepared product was suitable for further processing and distribution to other workplaces for further analysis and research.

In general, the lyophilisation has several steps.

2.1.Freezing

On a larger scale, freezing is usually done using a freeze-drying machine. In this step, it is important to cool the material below its triple point, the lowest temperature at which the solid and liquid phases of the material can coexist. This ensures that sublimation rather than melting will occur in the following steps. Larger crystals are easier to freeze-dry. To produce larger crystals, the product should be frozen slowly or can be cycled up and down in temperature. This cycling process is called annealing. However, in the case of food, or objects with formerly-living cells, large ice crystals will break the cell walls, resulting in the destruction of more cells, which can result in increasingly poor texture and nutritive content. In this case, the freezing is done rapidly, in order to lower the material to below its eutectic point quickly, thus avoiding the formation of ice crystals. Usually, the freezing temperatures are between −50 °C and −80 °C [2]. The freezing phase is the most critical in the whole freeze-drying process, because the product can be spoiled if badly done. Amorphous materials do not have a eutectic point, but they do have a critical point, below which the product must be maintained to prevent melt-back or collapse during primary and secondary drying [2].

2.2. Evacuation and primary drying

During the primary drying phase, the pressure is lowered (to the range of a few millibars), and enough heat is supplied to the material for the water to sublime. The amount of heat necessary can be calculated using the sublimating molecules' latent heat of sublimation. In this initial drying phase, about 95% of the water in the material is sublimated. This phase may be slow (can be several days in the industry), because, if too much heat is added, the material's structure could be altered.

In this phase, pressure is controlled through the application of partial vacuum. The vacuum speeds up the sublimation, making it useful as a deliberate drying process. Furthermore, a cold condenser chamber and/or condenser plates provide a surface(s) for the water vapor to re-solidify on. This condenser plays no role in keeping the material frozen; rather, it prevents water vapor from reaching the vacuum pump, which could degrade the pump's performance. Condenser temperatures are typically below −50 °C [1, 4]. It is important to note that, in this range of pressure, the heat is brought mainly by conduction or radiation; the convection effect is negligible, due to the low air density.

2.3. Secondary drying

The secondary drying phase aims to remove unfrozen water molecules, since the ice was removed in the primary drying phase. This part of the freeze-drying process is governed by the material's adsorption isotherms. In this phase, the temperature is raised higher than in the primary drying phase, and can even be above 0 °C, to break any physic-chemical interactions that have formed between the water molecules and the frozen material. Usually the pressure is also lowered in this stage to encourage desorption (typically in the range of microbars, or fractions of a Pascal). However, there are products that benefit from increased pressure as well. After the freeze-drying process is complete, the vacuum is usually broken with an inert gas, such as nitrogen, before the material is sealed. At the end of the operation, the final residual water content in the product is extremely low, around 1% to 4% [3].

3. RESULTS AND DISCUSSION

In regard to the organic solvent acetone, residues were determined after its evaporation from extracts by Hot space GC method (gas chromatography). The results of the determination of acetone residues are in interval from 0.06 to 0.13 % m/m. The extract does not contain any solvent residue.

The process of freeze-drying consists of the standard phases [1, 4]:

- Freezing - at atmospheric pressure,
- Evacuation - reducing pressure and primary drying - sublimation action - turning solid to gas and its dissipation from space of lyophilization,
- Secondary drying - removal of residual moisture at increased temperatures its dissipation from space of lyophilization.

The work on optimization of lyophilization consisted of two parts:

- Optimization of dilution of sample: because extracts from plant become after evaporation of solvents thick viscous liquids, for a successful lyophilization was necessary to dilute them with purified water in quality that declares the European Pharmacopoeia (*Aqua purificata* PhEur). The ration 1: 1 is optimal for an extract from northern high bush blueberry.
- Optimization of lyophilization program: for each prepared extracts were tested and optimized various lyophilisating procedures with the most optimal process of lyophilization (Table 1 and Fig. 1) in order to finally achieve a dry lyophilized powder.

Table 1 Optimize Lyophilisation Programme for Anthocyanin Extract of Bush blueberry

Section	Temperature (°C)	Vacuum (μBar)	Time (min)	Step
1	5	0	1	Loading
2	-30	0	60	Freezing
3	-30	0	120	Freezing
4	-30	200	30	Evacuation
5	-5	200	420	Drying
6	-5	200	240	Drying
7	5	200	330	Drying
8	5	200	210	Drying
9	35	200	240	Drying
10	35	100	240	Drying
11	35	50	270	Drying

NOTE: The parameter of vacuum: 0 is shown in lyophilization. This value indicates that in a chamber was atmospheric pressure. Pressures shown in μbar mean reduction of pressure in regard to atmospheric pressure.

In regards to our experiences, the optimal extraction method and the process of freeze-drying for obtaining pure anthocyans from fruits of the bush blueberry (*Vaccinium corymbosum* L.) were developed. After lyophilization biological properties (antimicrobial and antioxidant properties) and the stability of anthocyanins were successfully tested.

Freeze-drying is a relatively expensive process. The equipment is about three times as expensive as the equipment used for other separation processes, and the high energy demands lead to high energy costs. Furthermore, freeze-drying also has a long process time, because the addition of too much heat to the material can cause melting or structural deformations. Therefore, freeze-drying is often reserved for materials that are heat-sensitive, such as proteins, enzymes, microorganisms, and blood plasma [5, 7]. The low operating temperature of the process leads to minimal damage of these heat-sensitive products in our case the anthocyanins.

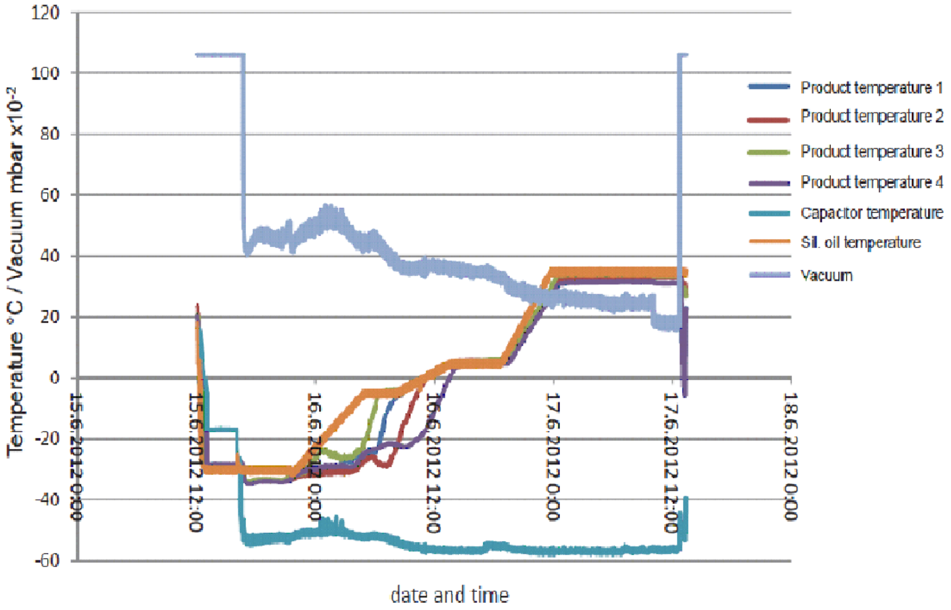

Fig. 1 The Courses of Temperature and Vacuum of Acetone Extract
Vaccinium corymbosum L..

The Freeze-drying is used to preserve food, the resulting product being very lightweight [5]. Another example from the pharmaceutical industry is the use of freeze drying to produce tablets or wafers, the advantage of which is less excipient as well as a rapidly absorbed and easily administered dosage form. In chemical synthesis, products are often freeze-dried to make them more stable, or easier to dissolve in water for subsequent use. In bio separations, freeze-drying can be used also as a late-stage purification procedure, because it can effectively remove solvents. Furthermore, it is capable of concentrating substances with low molecular weights that are too small to be removed by a filtration membrane [7].

4. Conclusions

In regard to our experimental results, freeze-drying for obtaining pure anthocyans from fruits of the bush blueberry (*Vaccinium corymbosum* L.) had these characteristics the drying temperatures: from +5° C (a primary drying temperature) through -31° C (sublimation point) to +35° C (a secondary drying temperature), the maximum drying pressure: 200 µbar and total time of lyophilization was about 36 hours.

Our research work was done in cooperation with the pharmaceutical company Medicproduct, Co. in Lipany (Slovakia), which uses freeze-drying to increase the shelf life of products, such as vaccines and other injectable. By removing the water from the material and sealing the material in a vial, the material can be easily stored, shipped, and later reconstituted to its original form for injection. Our new original research deals with an optimize extraction and freeze-drying procedures in order to the natural components. The purpose is carrying out a dry, quality lyophilized product, which is then submitted to further analytical and biological testing.

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Case study

INFLUENCE OF AIR TEMPERATURE AND RELATIVE HUMIDITY IN THE HOT PHASE OF KAJMAK FORMATION

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Abstract: *Kajmak is a traditionally made Serbian dairy product which can be classified between cheeses and butter. In the traditionally production, heat and mass transfer processes at milk/air contact surface are highly dependent on the environmental conditions, resulting in uneven product quality. In order to carry out the industrialization of kajmak production, it is necessary to reduce the production time, to introduce the environmental conditions control and to manage mass and energy transfer. Initial stage of kajmak production (first 60 min of kajmak formation process) results in surface coagulation of top layer of milk, due to mutual influences of: surface tension driven fat and protein concentration increase; and water evaporation driven by high milk temperature. This paper presents research on influence of air temperature and relative humidity in hot (initial) phase of kajmak formation. Variation of these parameters are shown trough the emitted heat flux from milk surface. Given mathematical model is validated by experimental data obtained by measuring milk and moist air parameters over 60 minutes. Statistical analysis of numerical and experimental data has shown good agreement.*

Key words*: kajmak, heat and mass transfer, convective and evaporative cooling, numerical modeling*

1. INTRODUCTION

Kajmak is a traditionally made Serbian dairy product which is primary produced in households and small dairy craft plants. It is characterized by a specific composition and sensory characteristics, based on which it can be classified between cheese and butter [7]. In Serbia, kajmak has traditionally been made in a number of rural households. Manufacturing process is not standardized and varies depending on the region of production [2]. Moreover, great variety of conditions in which it is produced, results in very large variation of composition and quality, which prevents its spread and organized approach to the market [1].

The process of kajmak formation can be divided into two phases: warm (initial) and cold phase. Warm phase represents surface coagulation of the top layer of milk, due to mutual influences of: water evaporation driven by high temperature of milk; and concentration of fat globules and proteins at milk/air interface. As a result of this process a skin layer is formed on top of the milk, and it represents the basis of kajmak.

Ambient conditions, i.e. the parameters of air have a strong influence in process of kajmak production [3]. During the whole process of kajmak formation, milk is continuously cooled with surrounding air. This energy exchange is of convective and evaporative nature, but with different dynamics during the course of the process. Evaporation process has the highest intensity at the beginning, and then, as the process progresses, it slows down due to the formation of skin on milk surface. Analysis of first 60 minutes of kajmak formation process [5] showed that readjustments of air parameters in controlled industrial kajmak production, level unchanged, can produce similar changes in the total energy flux as in the traditional method of production. It is also determined [4] that changes in air velocity during the initial 60 minutes of warm phase affects on yield and composition of skin layer.

The aim of this study and further investigation is understanding of air parameters influence on heat and mass balances in the warm phase of kajmak formation (first 60 minutes) in the purpose of creating a wider basis in scientific knowledge of the processes of kajmak forming that would help in finding possibilities of industrialization of this specific milk products.

2. MATERIAL AND METHODS

2.1 The skin layer samples production

The dynamics of the mass and energy exchange during the initial stage of kajmak formation was observed during the first sixty minutes of the process. Raw milk from the dairy farm PIK Zemun, standardized to 4% fat and 3.4% proteins (by adding cream and protein powder Promilk 852 A2, Ingredia, France) was used.

Milk heat treatment was carried out by heating the milk to 95°C, with regime: 85°C/10 min. and 95°C/10 min. After the heat treatment 3 kg of milk (at 95°C) was poured into a round vessel, dimensions 0.24 x 0.100m (diameter x length), and placed in a channel-type laboratory installation for kajmak production. The height of milk level in the vessel was 0.065 m. Air flow, with controlled temperature and relative humidity (RH), streamed through the channel, with a constant speed of 0.7 m/s for 60 minutes, flowing over the vessel and milk surface and along the side of all the vessel surfaces. The process of skin formation was monitored in five experiments (C1–C5), in which air inlet parameters varied as shown in Table 1. All experiments were carried out in triplicates.

Table 1. The parameters of outside air

Skin layer	Temperature [ºC]	RH [%]
C1	30	50
C2	30	70
C3	30	90
C4	40	70
C5	20	70

The laboratory installation for kajmak production (Termoklima, Beograd) consists of 0.2x0.3m tunnel and elements for air inlet preparation: fan, cooler, heater and air humidifier. Temperature, relative humidity and air flow were measured by Kestrel 4000 NK instruments (USA).

2.2 Mass and energy balance

The amount of water evaporated from milk and absorbed by the air stream can be determined using the following equation [9-11]:

$$\frac{1}{A}\frac{d\dot{m}}{d\tau} = -\lambda\left(\varphi p_s - p_a\right) = -D_{12} \qquad (1)$$

where are:
ϕ - an activity coefficient, which has a constant value for water
D_{12} - a binary diffusion coefficient
A – contact surface
p - partial pressure

Mass and heat exchange can be expressed by the following expression:

$$\frac{\partial\omega_1}{\partial\tau} + \frac{2D_{12}}{\omega_1+\omega^0}\left(\frac{\partial\omega_1}{\partial y}\right)^2 - \frac{\partial}{\partial y}\left(D_{12}\frac{\partial\omega_1}{\partial y}\right) = 0 \qquad (2)$$

where:
ω – water mass ratio

This equation is numerically solved simultaneously in order to obtain a solution for the sensible and latent heat fluxes at a certain point in time. The boundary conditions applied are as follows:

$$\frac{\partial \omega_1}{\partial y} = 0,\ z = 0$$

$$\frac{d}{d\tau}\int_0^l \rho_1 dz = -\, j_{1,s} \qquad (3)$$

$$\rho_1^0 \frac{dl}{d\tau} = -\, j_{1,s}$$

Dimensionless criteria have an important role in describing the flow field and the overall phenomenon of the mass and heat transfers. Since the conduction and diffusion are described by Fourier's and Fick's laws respectively, which have the same mathematical form, it may be appropriate to establish an analogy between the convective heat and mass exchange. Accordingly, in order to describe the phenomenon of convective mass exchange, Prandtl's number should be replaced by the Schmidt number, and Nusselt's number by Sherwood's number. Based on the presented analysis for modeling the phenomenon of simultaneous mass and heat exchange, the following equation can be derived:

$$Nu = 0.664 \cdot \mathrm{Re}^{1/2} \cdot \mathrm{Pr}^{1/3} \qquad (4)$$

$$Sh = 0.664 \cdot \mathrm{Re}^{1/2} \cdot Sc^{1/3} \qquad (5)$$

3. RESULS AND DISCUSSION

3.1 The Mass balance

Quantity and dynamics of water evaporation measured during the first 60 minutes are shown in Table 2. The effect of air temperature at a relative humidity of 70 % and the effect of relative humidity at 30 ° C, on the dynamics of the evaporation of water are shown in Figure 2 and Figure 3 respectively.

Airflow parameters affect on quantity of evaporated water, which can be seen from Table 1. The intensity of evaporation is very intensive in first stage of skin layer formation in all experiments. During the first 5 minutes, the character of evaporation curves in all experiments is different, but after this period curves were almost identical. After this period, water evaporation is decreasing which is result of combined milk cooling and skin layer formation due to heat transfer from milk side to air stream. In this stage evaporation process is stabilized, which is result of stable water mass transfer trough the formed skin layer.

Increase of water evaporation speed goes along with airflow temperature decrease and differences between experiments are most noticeable in first 2 minutes of process, when skin layer formation occurs.

Table 2. Amount of evaporated water in first 60 minutes of kajmak formation

Time [min]	Evaporated water [kg/s]				
	C1	C2	C3	C4	C5
0	0,00271	0,00352	0,00530	0,00324	0,01017
2	0,00226	0,00244	0,00264	0,00185	0,00235
5	0,00109	0,00118	0,00120	0,00117	0,00122
10	0,00076	0,00060	0,00068	0,00070	0,00066
20	0,00046	0,00038	0,00037	0,00039	0,00033
30	0,00031	0,00026	0,00024	0,00027	0,00023
40	0,00024	0,00020	0,00018	0,00021	0,00016
50	0,00017	0,00016	0,00014	0,00016	0,00012
60	0,00016	0,00012	0,00012	0,00013	0,00009

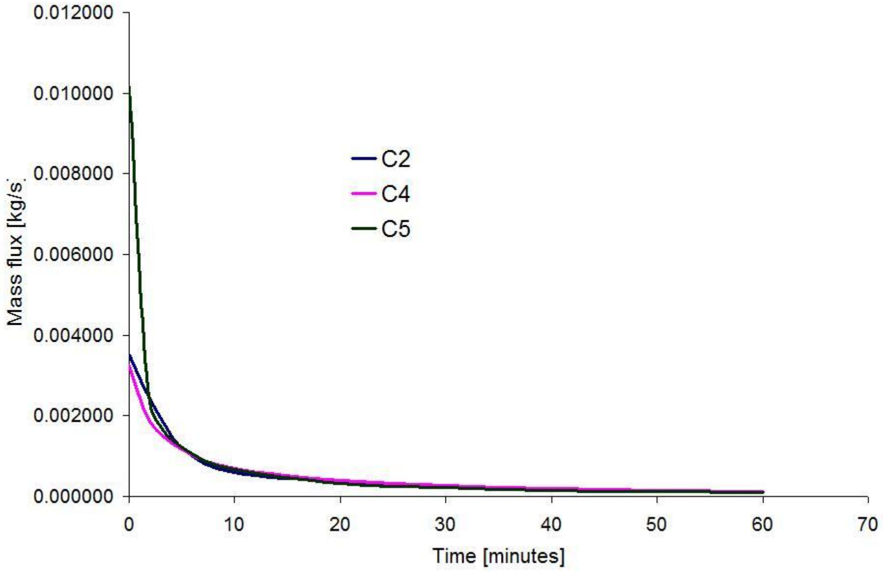

Fig 1. Intensity of evaporated water in first 60 minute in function of RH 70% and different airflow temperatures

In first stage during the 10 minutes, greatest amount of evaporated water is removed in experiment C5 at airflow temperature of 20°C, and smallest in experiments C4 at airflow temperature of 40°C. During the first 2 minutes of milk cooling process, the amount of evaporated water in all experiments were the greatest. In experiment C5 in first 2 minutes the amount of evaporated water (0,01252kg) is about 82% of whole evaporated water in hot phase of skin layer formation (60 minutes of process). Compared with amounts in first 10 minutes, this is almost 87% of whole evaporated water.

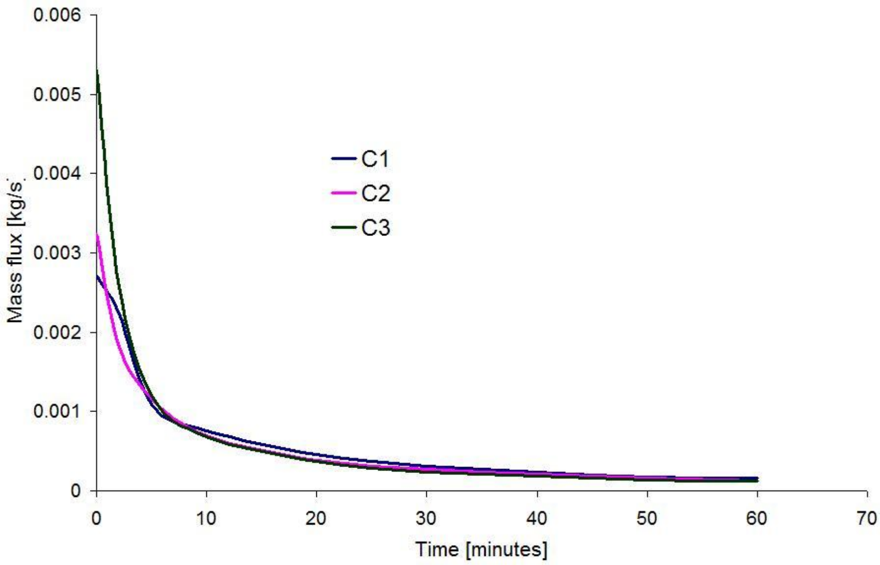

Fig 2. Intensity of evaporated water in first 60 minute in function of airflow temperatures (30ºC) and different RH

At lower RH values and air temperature of 30°C, ability for water absorption of air is increasing, which can be seen at Fig 2. From the data in Table 1, at this airflow temperature and RH range from 50 up to 90% in first 10 minutes evaporated water is in range from 0.00682 up to 0.00983kg. Values were greatest in experiment C3 where RH was at the highest values. This can be explained with the fact that skin layer in experiment C3 had a lower content of dry matter in comparison with experiments C1 and C2 where the porosity of skin layer was bigger. Another reason for this kind of evaporation is strong influence of airflow temperature which speeds up milk cooling (convective part).

3.2 The energy balance

Values of heat flux transferred in warm phase are shown in Table 3. Influence of heat transfer in time for all experiments is given at Fig 3. Influence of airflow temperature on heat transfer during the warm phase at RH 70% is shown at Fig 4, and influence of RH on heat transfer in warm phase at constant airflow temperature of 30°C is shown in Fig 5.

Similar to the evaporated water consideration, from Table 3 it can be seen that airflow temperature and RH have a strong influence on heat transfer in warm phase. In first 60 minutes, overall heat flux, transferred from the cooling milk to surrounding airflow is in range of 1.0556 kW (experiment C1) up to 1.6302 kW (experiment C5).

Table 3. Values of heat flux in first 60 minutes of kajmak

Time, [s]	Heat flux, [kW]				
	C1	C2	C3	C4	C5
0	0	0	0	0	0
120	0,0942	0,1674	0,2616	0,2930	0,4639
300	0,3523	0,3395	0,3465	0,2279	0,3046
600	0,1465	0,2777	0,2274	0,2009	0,2526
1200	0,1277	0,1235	0,1605	0,1472	0,1898
1800	0,1162	0,1095	0,1249	0,1026	0,1179
2400	0,0827	0,0893	0,0837	0,0802	0,1207
3000	0,1057	0,0656	0,0823	0,0684	0,1005
3600	0,0303	0,0865	0,0551	0,0621	0,0802
Σ, [kW]:	*1,0556*	*1,2591*	*1,3421*	*1,1823*	*1,6302*

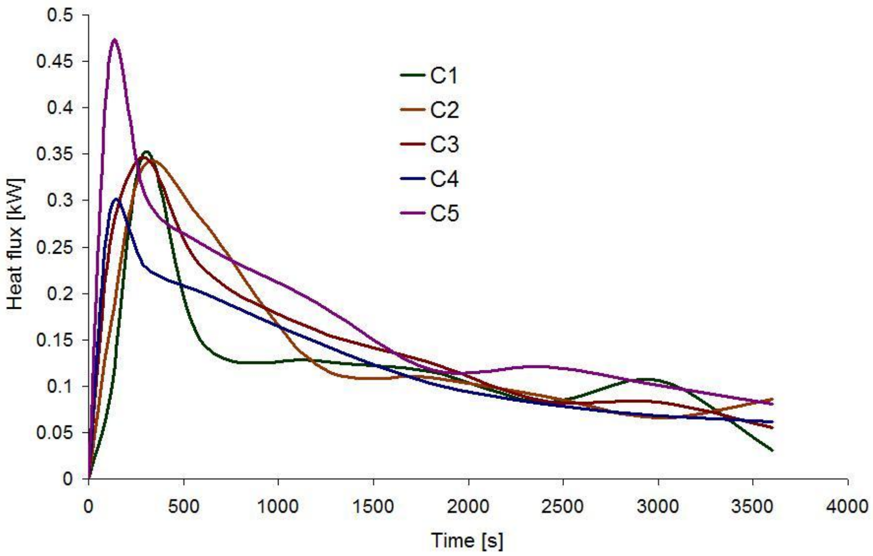

Fig 3. Intensity of heat transfer flux in first 60 minute in function of time

It can be clearly seen from Fig 3. that in all experiments, heat transfer from milk to airflow in early stages is very unstable. This is explained with currently changeable airflow parameters, and also with variation in local airflow velocities around the milk vessel. After the skin formation, which happens in short time, heat transfer from milk to airflow gets mainly convective and it stabilises [5]. After approximately 500 s stationary convective heat transfer is established. This is consequence of weakening of intensive water evaporation. More stable heat transfer occurs after 1800 s from inserting milk vessel to airflow.

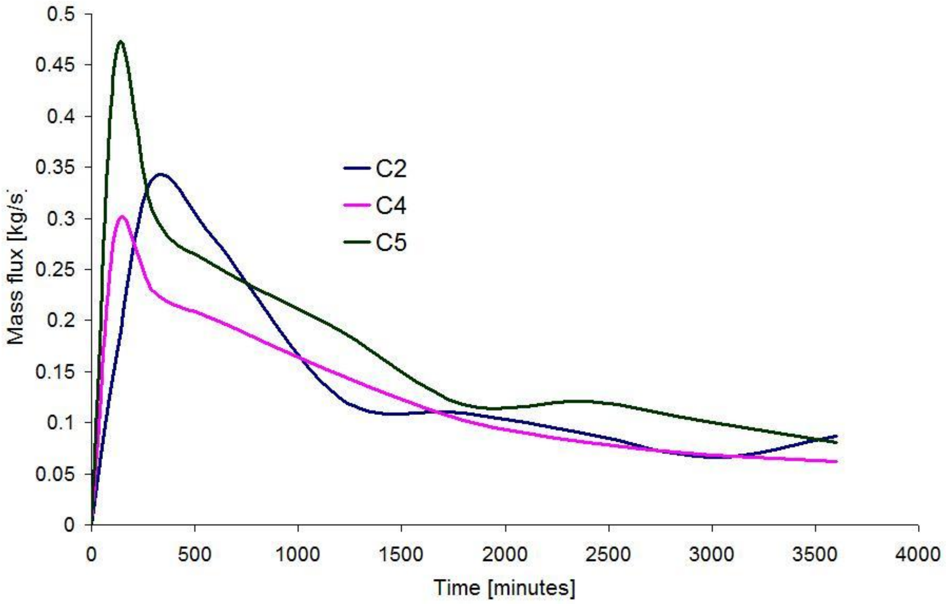

Fig 4. Intensity of heat transfer flux in first 60 minute in function of RH 70% and different airflow temperatures

Airflow temperature has strong impact on heat transfer mechanism of skin formation. Fig 4. shows that the greatest heat flux is founded in experiment C5, which had the smallest temperature value (20ºC). With higher temperature differences between milk and airflow, driving force for convective heat transfer, like in C5 will produce intensive milk cooling and higher value of heat fluxes. Temperature change from 20ºC in C5 experiment up to 40ºC in C4, changes heat flux values for almost 30% (from 0.33 kW in C4 up to 0.47 kW in C5 in first 300 s).

With the same temperature (30 ºC) and different RH values, peak value of heat flux in first 300 s is almost identical (varies from 0.33 kW up to 0.35kW), which is shown in Fig 5. Significant differences in curves characteristics are present in later period (from 300 s until the end of warm phase), but it can be said that heat transfer is relatively stable. Reason for these differences lies in the fact that a higher RH values produce probably more porous structure of skin layer. These data are in compliance with data from mass balance and can be explained with skin structural characteristics which are changed significantly in time. With increasing of skin thickness, evaporation loses significant, and convective heat transfer becomes dominant.

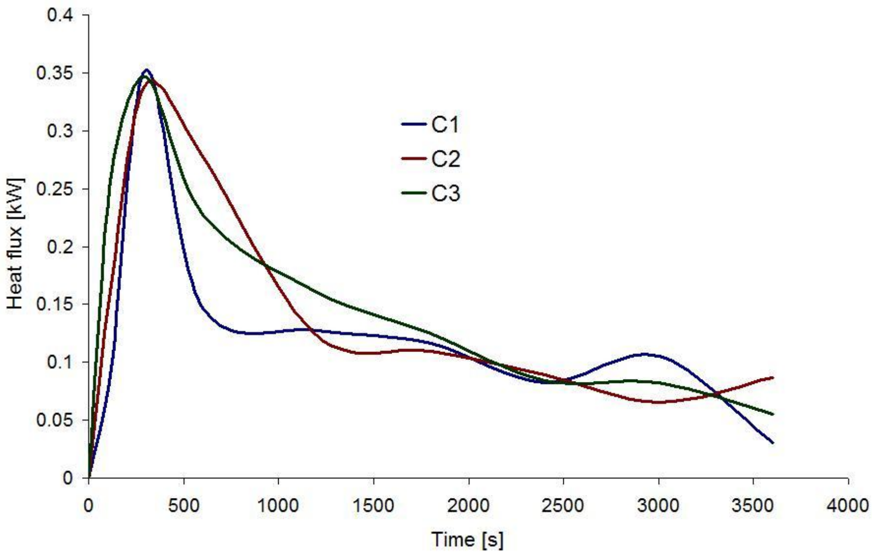

Fig 5. Intensity of heat transfer flux in first 60 minute in function of airflow temperature at 30ºC and different values of RH

4. CONCLUSION

The aim of this paper was establishing relationship between airflow temperatures and relative humidity on heat and mass transfer mechanism in process of skin layer formation in first 60 minutes. From the experiments it can be concluded that evaporative and energy changes are very unstable in first stage, immediately after milk is inserted into airflow. As the skin formation occurs, these changes becomes more stable. In first 2 minutes in all experiments, the greatest amount of water is evaporated, which is consequence of milk and airflow direct contact. After this period, depending on skin layer porous structure, water evaporation is still present, but values of these mass fluxes become smaller. Considering the airflow relative humidity on heat and mass balances it is necessary to take into account very complex relations with temperature and influence of both parameters on skin porous structure formation. Results also can show optimal values for airflow temperature and relative humidity in the purpose of process controlling, and obtaining of satisfactory structure of kajmak in industrial production.

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Original scientific paper

UNIVERSAL MODEL FUNCTION FOR THE CHANGES OF MANURE FERTILIZING PROPERTIES

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Abstract. *Solid manure crucially changes its fertilising properties during the aerobic treatment. In present study, the contents of water, organic matters, mineral matters, total and soluble nitrogen, phosphorus-pentoxide and kalium-oxide, as well as PH-value has been measured during the period of seven weeks of aerobic fermentation. Among other changes, the increase of amounts of N, P_2O_5 and K_2O, of more than 300% in average with respect to raw solid manure at the begining of the process, has been evidenced. However, it has been found and experimentally verified that changes of all of analyzed properties generally follow an exponential laws, analytically described by function $y = e^{a+bx+cx^2}$, with respect to the length of fertilising period as independent variable x.*

Key words: *manure, aerobic treatment, fitting function, exponential law*

1. INTRODUCTION

The aerobic processing of solid cattle manure (composting) is one posibillity among other available solutions for reducing and elimination of the risks, which come with inappropriate manure handling. Omitting, as well as an inadequate manure treatment, results in uncared manure that can lead to severe problems such as underground water pollution by organic pollutants, eutrophication, pathogen bacteria release that can contaminate soil and water, etc. Inadequate treatment (processing) procedures can consequently produce low-quality manure characterised by: bad physical – mechanical properties, low nutritive value, uneven quality, a lot of unwanted mechanical impurities, etc. In addition, manure of this kind may have many other strong negative effects, especially on the manipulation equipment [1].

Manure processing procedures should provide recycling of pathogens commonly immersed in the animal excrements and litter, as well as recycling of weed seeds that are resistant to physiological processes in the intestinal tract of animals and fermentation process. To reach this goal successfully, large area is required for raw manure fermentation and mature manure storage. In addition, manure handling, transport and land distribution demands high energy consumption. However, aerobic treatment significantly simplifies overall manure handling processes, shorten the manure maturation period by reducing it from 260-345 days to approximately 45 days [2] and strongly decreases energy consumption. At the same time, aerobic treatment provides a high quality product in terms of its nutritional and ecological value [3].

Manure composting treatment, based on application of wheat straw as a filler, requires researching the properties of both components, especially when joined together. Mutual inter-relations between these components are of special importance for a successful composting process. Their ratio depends directly on the amount of straw used as litter. Amount of straw used for the procedure also depends on the C **:** N ratio, which should be in range between 18 **:** 1 and 20 **:** 1. This procedure encourages development of aerobic microorganisms, which purpose is to break down organic matter with development of high temperature [4].

The maximum temperature, which reaches the range of 70 to 75 °C in this zone, retains about 1/3 of the time of care. In that period, biothermical processes occur, supported with thermophilic microorganisms and followed by high temperature and pH and other biochemical changes that relatively fastly destroy pathogenic microorganisms in the product. At the same time, because of the high temperature, germination ability of weede vanish. The process of treament lasts for seven weeks, assuming around 12 mass treatments during this period [1].

2. MATERIAL AND METHODS

In this paper are analysed temporal changes of the properties of fresh, raw dairy manure joined with weath straw, exposed to aerobic fermentation process. The contents of water, organic matters, mineral matters, and total soluble nitrogen, phosphorus-pentoxide and potassium-oxide, as well as pH-value has been measured during the period of seven weeks of aerobic fermentation.

Table 1: Physical and chemical properties of crude solid manure at the beginning of aerobic fermentation process.

Water content (%)	Mineral matter (%)	Organic matter (%)	pH [-]	N (%)	P_2O_5 (%)	K_2O (%)
78,34	2,77	97,22	7,72	0,77	0,36	0,46

Dry matter content of the fresh manure was about 20%, while mutual ratio of components varied from 1 kg **:** 5 l up to 1 kg **:** 7 l in different acqured samples. This way, an average dry matter content in joined mass, at the beggining of procedure was 22%. Components joining has been performed in a common way, in the manure cleaning channels inside of the dairy barn: raw manure was deposited to the concrete plateau in prismatic piles of 3 m wide and 1 m high. Length of the prisms is not essential to the process. Physical and chemical properties of crude solid manure at the beginning of aerobic fermentation are given in Table 1.

Fig. 1: The prototype of self proppeled machine KOMPO MAT-1.

Care of the joined mass has been performed periodically for seven weeks, using a prototype of self-propelled machine KOMPO MAT-1 (Fig. 1): three times in the first week, and twice in the period from the second to the sixth week. During the last (seventh) week, treatment was not performed. Working speed of this machine varied in the range between 0.1 km/h and 0.7 km/h.

Experimental data points of all measured parameters of joined mass were fitted against the exponential function

$$y = e^{a+b\cdot x+c\cdot x^2}\,. \tag{1}$$

Numerical values of parameters *a*, *b* and *c* were adjusted by the least-square fit approach [5, 6], using the software package – R [7]. The fitting quality was estimated following the common approach, i.e. on the base of R-square values and root-mean-square errors, or simply the standard errors (RMSE/SE).

3. RESULTS AND DISCUSSION

With aging, i.e. during the treatment of aerobic fermentation, changes of all measured manure parameters have tightly followed the exponential law, described by expression (1). The only exclusion of this statement is the change of soluble nitrogen (N) content - it did not followed this law ideally, but still fairly good. During the aerobic fermentation process, the values of some fermented manure parameters increase, while the values of some other parameters decrease in time. However, in all cases of interest, the changes of manure properties were accurately described by the exponential law having the exponent

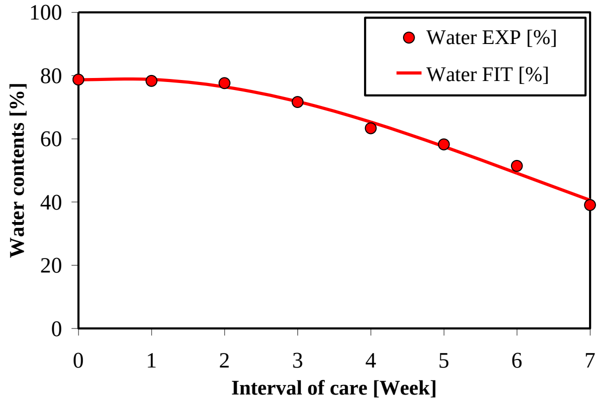

Fig. 2: Water contents in the manure during aerobic fermentation.

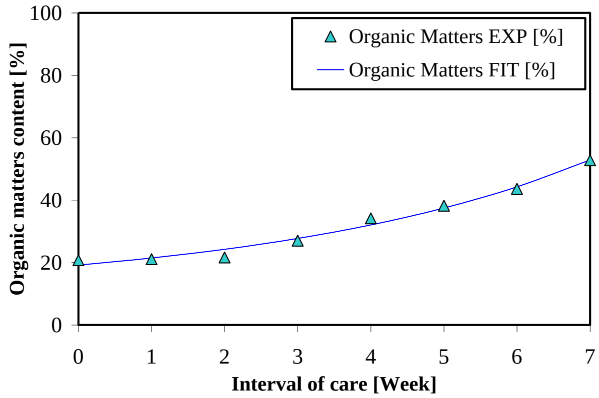

Fig. 3: Organic matters contents in the manure during aerobic fermentation.

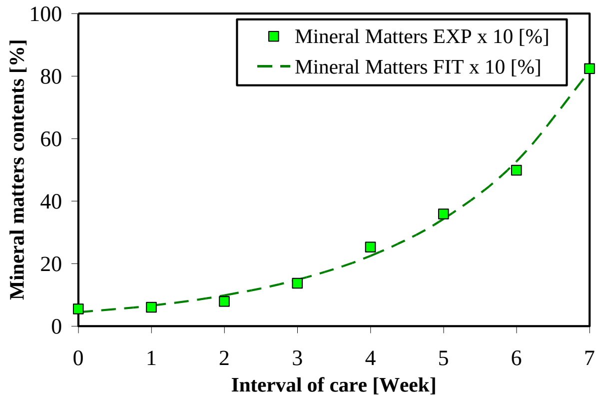

Fig. 4: Mineral matters contents in the manure during aerobic fermentation.

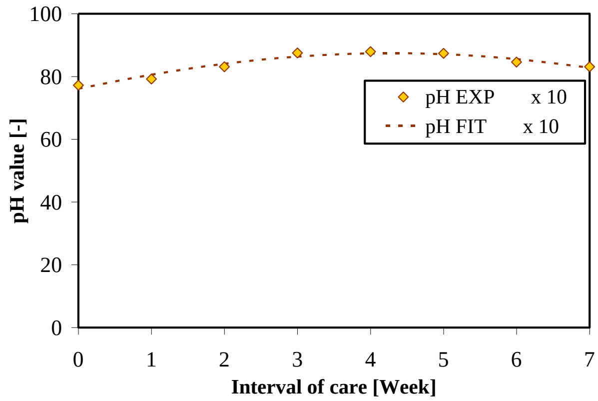

Fig. 5: Changes of the pH value of the manure during aerobic fermentation.

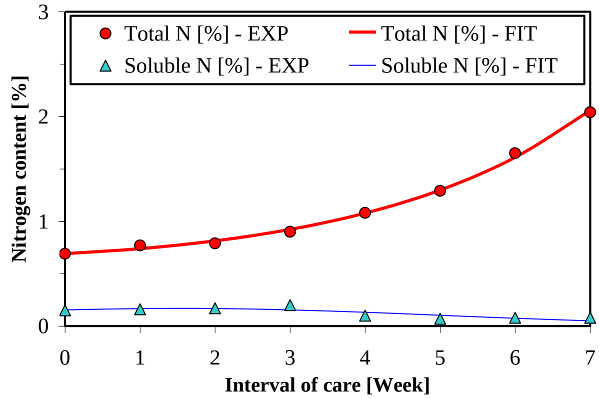

Fig. 6: Changes of the total and soluble nitrogen (N) content during aerobic fermentation.

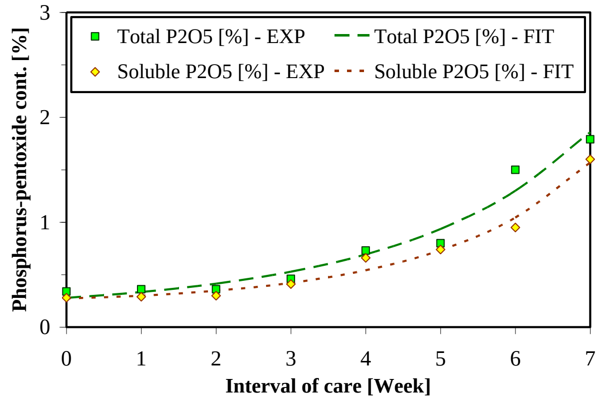

Fig. 7: Temporal changes of the total and soluble phosphorous-pentoxide P_2O_5 content in the manure, during aerobic fermentation.

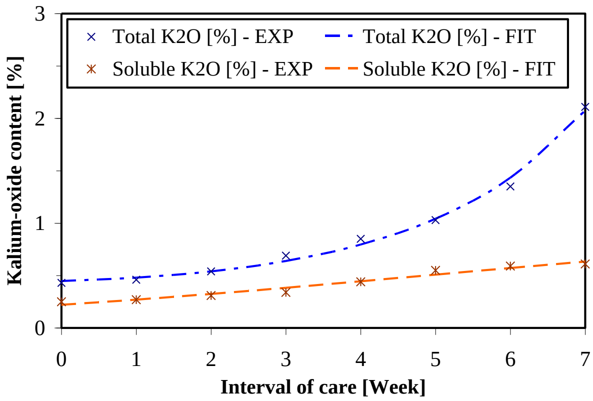

Fig. 8: Temporal changes of the total and soluble total and soluble kalium-oxide K_2O content in the manure, during aerobic fermentation.

in the form of the second-order polynom. Experimental verification of this statement is provided in the Figs. 2 - 8, and Table 2.

Table 1: Fitting constants and quality (i.e. accuracy) parameters.

	a	b	c	R^2	Root MSE (SE)
WaterContent [%]	4.36492359877999	0.01771213714978	-0.01603877402647	0.991	1.6677
Mineral Matter Content [%]	1.48758417547268	0.39232157451419	0.00341464514777	0.995	2.2660
Organic Matter Content [%]	2.95317260459025	0.10675493806300	0.00546078257706	0.984	1.7639
pH [-]	4.33236629713845	0.06449961914824	-0.00749941411451	0.939	1.1566
Total N [%]	-0.36868262391441	0.05123028731635	0.01493642722995	0.998	0.0283
Soluble N [%]	-1.87118299561023	0.12304984544536	-0.04061098486809	0.699	0.0322
Total P_2O_5 [%]	-1.28040020252070	0.17091414704976	0.01436027227095	0.965	0.1238
Soluble P_2O_5 [%]	-1.29649896558883	0.06581925307679	0.02623424147155	0.982	0.0726
Total K_2O [%]	-0.80341942446222	0.04369671738379	0.02504086780918	0.994	0.0540
Soluble K_2O [%]	-1.50747839320489	0.20728171574211	-0.00819686413002	0.964	0.0330

Analysis of the fitting accuracy is based on the most commonly used parameters: R-square factor and root-mean-squre error (or simply the standard error). Both of these two estimation parameters indicates the high accuracy of fitting procedure, which follows the exponnetial function (1). For example, this statement can be illustrated by the fact that R-square factor reached vales over 0.95, except for the soluble nitrogen (N) content (0.699). More detailed information on the fitting accuracy is availble in Table 1.

4. Conclusions

Mathematical modeling of the various processes and operations in contemporary agriculture has been strongly intensified during the last few decades. Consequently, the importance of different approaches of such kind in modern agriculture has become recognized worldwide. Following these trends, in this study are measured and analyzed changes of solid manure properties during the aerobic fermentation. Experiment has been performed during the period of seven weeks. Measurement comprehended the contents of water, organic matters, mineral matters, total and soluble nitrogen (N), phosphorus-pentoxide (P_2O_5) and kalium-oxide (K_2O), as well as PH-values.

Among changes of other manure properties, the increase of amounts of N, P_2O_5 and K_2O, of more than 300% in average with respect to raw solid manure at the begining of the process, has been evidenced. However, it has been found and experimentally verified that changes of all of analyzed properties are mutually different, but still generally follow an analytical law of the same kind. More precisely, changes of each of these properties can be accurately analytically described by exponetial function $\mathbf{y = e^{a + b\,x + c\,x^2}}$ with respect to the length of fertilising period as independent variable **x** (weeks).

The basic benefit of approximating (i.e. modeling) the experimental data of any kind, with some appropriate analytic function, is to describe a larger amount of empirical data with just a few parameters. These parameters are constants (coefficients) in the adopted model function, $\mathbf{y = e^{a + b\,x + c\,x^2}}$ in present study, which are evaluated through some kind of a fitting procedure. This way, known analytical function that represents explicit form of dependency of some specified solid manure property on the temporal duration of aerobic fermentation can be used to easily predict the numerical value of this property in advance, at the beginning phases of the fermentation process. In addition, the model functions of this kind can be useful for future development of models that describe more complex processes based on production or application of solid manure.

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Original scientific paper

STATISTICAL ANALYSIS OF SOME BIOLOGICAL AND TECHNOLOGICAL CHARACTERISTICS FOR VARIETIES AND LOCAL BIOTYPES OF VINES IN WESTERN ROMANIA

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Abstract *Over 16 local varieties and biotypes of vines from the western part of Romania, have been identified and analyzed in terms of the biological and technological traits. The results were analyzed through comparison with some known and common varieties in the area. The quantitative and qualitative results for these varieties, were interpreted on the basis of statistical and mathematical models and finally applied to multivariate analysis. In addition to statistical interpretation that provides accuracy data, it was revealed the special value of some of these local varieties and biotypes.*

Key words: *Local biotypes, Wine, Statistical analysis, Romanian viticulture*

1. INTRODUCTION

The number of existing grapevine varieties on Earth is estimated to be 10-12 thousands. Such large number of varieties shows that vine is a plant with high genetic variability and the presence of these species in different areas proves that vine plants can adapt to different environmental conditions [1]. Local varieties and biotypes are an important source of biodiversity and also a valuable source for getting genuine typical products, able to impose on the wine market in which a large number of consumers are looking for locally specific products [2, 3].

In recent years, both globally and locally, there is a tendency to restore the importance of local varieties. These varieties must be known, protected and preserved, being a part of Romanian wine tradition, their research and promotion helping to improve the scientifically viticulture and to develop the viticulture practice [4]. In the international wine growing research, an important issue and more and more current is the local capitalization potential of each area in order to obtain authentic products, typical for each areas, that bring diversity, which can cope with a competition becoming fiercer [5].

2. MATERIAL AND METHODS

Researches were conducted in private gardens and vineyards in the Buziaş - Silagiu vineries area. During field trips were identified and sampled numerous varieties which were considered interesting, retained and pursued in research of 26 local varieties and biotypes, from which 16 varieties are presented in this paper. Local varieties and biotypes identified and retained as interesting for research were analyzed and compared with the best known representative of the species from this area, in order to draw appropriate conclusions. Growth vigor on leaf area, yield per vine and yield stability were analyzed.

Determination of vines growth vigor was assessed by foliar surface. Total foliar surface was evaluated based on the average foliar surface of one leaf and on the average number of leaves on a vine. To calculate the foliar surface were analyzed 10 vine of each variety. From each vine all leaves were numbered and the average number of leaves on a vine was calculated, and then 10 medium leaves were chosen. Calculation of one leaf surface was performed by weighing using the hoops method. For the estimation and interpretation of genotype *x* environment interaction and stability of the various studied traits, different patterns of linear regression analysis were used. This method is based on the finding that different components of genotype x environment interaction are linearly correlated with the effects of environmental conditions expressed by the studied trait of the average performance of all genotypes [6].

For the regressions calculations, we used Finlay and Wilkinson [7] model, in which the average coefficient of regression of all genotypes is $b_i = 1$. The mathematical model [7] for linear regression analysis is:

$$F_{ij} = \mu + g_i + b_i t_j + \delta_{ij} + e_{ij} . \quad (1)$$

with the following parameters: F_{ij}, the average of genotype *i* in environment *j*;
μ, the overall average;
g_i, the effect of genotype *i*;
t_j, the environment *j* effect (the index);
b_i, the linear regression coefficient between the F_{ij} and t_j;
δ_{ij}, the deviations of F_{ij} from linear regression and
e_{ij}, the error associated with genotype *i* in the *j* environment.

Regression coefficient b_i expresses the value by which a genotype mean is changes when the mean of a particular environment increases or decreases by one. For genotype *i*, the regression coefficient is defined by:

$$b_i = \sum F_{ij} t_j / \sum t_j^2 . \quad (2)$$

A genotype relative adaptability to different environmental conditions is assessed by three parameters: average performance; genotype response to different environmental conditions (regression coefficient), performance stability (deviations from regression). According to Finlay and Wilkinson, varieties with values of *b* closed to 1 have finally the average stability. When the average stability is associated with a high yield, varieties are adapted to environmental factors with high yield and when the association is made with low production indicates a varieties adaptation to environmental factors of low productivity. Stability performance of a genotype in different environmental conditions can be evaluated by using the variance of deviations from the regression:

$$s_\delta^2 = \frac{1}{n-2}\left[\left(\sum F_{ij}^2 - \frac{\left(\sum F_{ij}\right)^2}{n}\right) - \frac{\left(\sum F_{ij} t_j\right)^2}{\sum t_j^2}\right] - \frac{\sigma_E^2}{r}. \quad (3)$$

where n represents the number of localities (areas), r the number of repetition and σ_E^2 denotes the error variance. The stability of genotypes performance grows when s_δ^2 decreases and tends to zero. In conclusion, the ideal genotype is that with a high average production, b_i= 1 and s_δ^2 =0. The significance of regression and genotypes deviation from the linear regression (Table 1) was performed by analysis of variance according to [8].

Another method used for assessing the stability is the *ecological valence method* ($W_i^{2\cdot}$) proposed by Wricke (1962) [9] for g_i genotype grown in different environmental conditions (n), and represents the contribution of each genotype to the sum of squared deviations for genotype x environment interaction and is calculated using the formula:

$$W_i^2 = \sum\left(Y_{ij} - Y_i - Y_j + Y\right). \quad (4)$$

where: Y_{ij}, represent the average performance of genotype i in environment j;
Y_i, the average performance of genotype i in all the environmental conditions tested;
Y_j, average of the locality (areas) j and Y is the overall average in the experience.

Table 1: Analysis of variance for the Hardwick and Wood [8] model.

Source of variance	**GL**	s^2	F
Total	*gn-1*		
Genotypes	*g-1*	M_1	M_1/M_5
Localities (Environment)	*n-1*	M_2	M_2/M_5
Genotype *x* Environment	*(g-1)(n-1)*	M_3	M_3/M_5
Regression heterogeneity	*g-1*	M_4	M_4/M_5
Error(regression deviation)	*(g-1)(n-2)*	M_5	

Low values for the coefficient W_i^2 shows a high ecological valence and also a high stability of genotype performances in specific environments.

In order to establish the significance of ecological valence, by the F test, it is necessary to compute the ecological valence variance of each genotype (s_{Wi}^2), and an average of ecological valence (W_{im}^2) for all the genotypes from experience:

$$s_{Wi}^2 = \frac{gW_i^2}{(g-1)(n-1)}. \quad (5)$$

$$W_{im}^2 = \frac{W_1^2 + W_2^2 + \ldots + W_g^2}{g}. \quad (6)$$

$$s_{Wim}^2 = \frac{gW_{im}^2}{(g-1)(n-1)}. \quad (7)$$

Experimental value $F = s_{Wi}^2 / s_{Wim}^2$ is compared with theoretical value for *n-1* and gn-*1* degrees of freedom. For analysis of genotype *x* environment interaction was used method 1 of the model developed by Muir et al. (1992) [10]. According to this model, the sum of squared deviations for genotype *x* environment interactions are separated into two components: one due to heterogeneity of genetic variance (HV) in different localities, and a component due to imperfect correlations (IC) and the differences among genetic correlations of a genotype rank ordering in different localities (environmental conditions):

- sum of squared deviations for genetic variance heterogeneity:

$$SP_{HV} = n\sum\left(Z_j - \overline{Z}\right)^2 . \tag{8}$$

- sum of squared deviations due to imperfect correlations:

$$SP_{IC} = \frac{2n}{e}\sum\left(1 - r_{jj'}\right)\left[Z_j Z_{j'}\right]. \tag{9}$$

- total sum of squared deviations (interaction genotype *x* environment):

$$SP_{GE} = n\sum(\overline{Y}_{ij} - \overline{Y}_i - \overline{Y}_j + \overline{Y}), \tag{10}$$

where

$$Z_j^2 = \sum(\overline{Y}_{ij} - \overline{Y}_j)^2 , \tag{11}$$

$$Z_{jj'} = \sum(\overline{Y}_{ij} - \overline{Y}_j)(\overline{Y}_{ij'} - \overline{Y}_{j'}), \tag{12}$$

$$r_{jj'} = Z_{jj'} / [Z_j Z_{j'}], \tag{13}$$

$\overline{Y}_{ij}$ - genotype *i* in environment *j* value;
$\overline{Y}_i$ - average mean of genotype *i*;
$\overline{Y}_j$ - environmental *j* average mean;
$\overline{Y}$ - overall average of the experience;
$r_{jj'}$ - correlation coefficient among the rank order of a genotype in environments *j* and *j'*;
e - number of localities.

Another statistical model used to determine stability was the stability variance analysis $\hat{\sigma}_i^2$, developed by Shukla (1972) [11]. According to this model, the author defines the genotype *i* variance stability, as its variance in all environmental conditions (localities) where it was tested, after the average effect of each locality (environment) was removed.

$$\hat{\sigma}_E^2 = \frac{MS(E) - MS(GE)}{p}, \tag{14}$$

$$\hat{\sigma}_i^2 = \frac{p}{(p-2)(q-1)}\sum_{j=1}^{q}\left(Y_{ij} + \bar{Y}_{i.} + \bar{Y}_{.j} + \bar{Y}_{..}\right)^2, \tag{15}$$

$$MS(E) = \frac{p}{q-1}\sum_{j=1}^{q}\left(\bar{Y}_{.j} - \bar{Y}_{..}\right)^2, \tag{16}$$

$$SS(GE) = \sum_{i=1}^{p}\sum_{j=1}^{q}\left(Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} - \bar{Y}_{..}\right)^2, \tag{17}$$

$$MS(GE) = \frac{SS(GE)}{(p-1)(q-1)}, \tag{18}$$

Testing the significance of the variance of each genotype is performed using the *F*-test for *(p-1)* and *(p-1)(q-2)* degrees of freedom, where *p* represent the number of genotypes and *q* the number of localities. This model developed by Shukla [11], allows to test the stability by regression heterogeneity variance analysis and also to compute the "balance" = the sum of squared deviations *G x M* – the sum of squared deviations regression.

A genotype is considered stable if the stability variance $\hat{\sigma}_i^2$ is equal to the environment variance σ_E^2. High values of the stability variance, shows a high instability of *i* genotype for the environmental conditions where it was tested. To study the genotype *x* environment interaction was used also a model for multivariate analysis, namely *the analysis of additive main effects and multiplicative interaction (AMMI)* after Gauch and Zobel (1992, 1996) [12, 13], Crossa J. et al. (1990) [14]. This statistical model combines the usual analysis of variance for additive main effects with principal component analysis for multiplicative effects of genotype *x* environment interaction using the following equation:

$$Y_{ij} = \mu + g_i + \varepsilon_j + \sum \theta_k U_{ki} V_{kj} + \rho_{ij} + e_{ijk}, \tag{19}$$

where: μ represent the *overall* mean of the experience;
g_i, the standard deviation of genotypes (compared to the overall average);
ε_j, the standard deviation of the localities (compared to the overall average);
θ_k, $IPCA_k$ individual value;
U_{ki}, the vector value of *i* genotype for the $IPCA_k$ axis;
V_{kj}, vector value of *j* locality for $IPCA_k$ axis;
ρ_{ij}, the residual value and finally,
e_{ijk}, the general error (of the experience).

The association among the results of different methods for assessing the stability of studied traits was conducted by using the Kendall coefficient of concordance (W). Coefficient of concordance W, has a linear relation with the average correlation coefficients of rank order r_S calculated for all pairs of each two sets of order rank

$$\bar{r}_S = \frac{m\,W-1}{m-1}, \tag{20}$$

where:

$$W = \frac{12S}{m^2(n^3-n)} = \frac{12S}{m^2(n-1)n(n+1)}, \tag{21}$$

$$S = \sum\left(R_j - \frac{\sum R_j}{n}\right)^2, \qquad (22)$$

m, represents the number of order ranks sets for n studied observations;
R_j, is the sum of order ranks for each observation in the m data sets;
S, is the sum of squared deviations among each R_j and the average for all R_j values.

In order to establish the significance of the coefficient concordance W, the experimental $\chi^2 = m\ (n-1)\ W$ was calculated, which is compared with the theoretical value for $n-1$ degrees of freedom.

3. Results and discussion

Foliar surface is an important indicator showing the photosynthetic potential of a variety, with direct influence on its productivity [15]. From this point of view, local varieties and biotypes were recorded in most of the cases higher values than witnesses, however, there were few varieties which recorded lower values than witnesses.

Most varieties of group for Table 2, grape varieties exceeded the witness regarding the foliar surface per vine.

Table 2: The foliar surface of local varieties and biotypes for table grapes (mean 2008-2010).

Variety/biotype	Foliar surface/vine (m²)				Difference toward the witness (m²/vine)	Significance
	2008	2009	2010	Mean 2008-2010		
Alb crocant de Buziaş	3,52	4,16	3,46	3,71	0,06	-
Alb lax de Silagiu	4,14	4,57	4,22	4,31	0,66	*
Auriu de Silagiu	3,15	3,61	3,33	3,36	-0,29	-
Coarnă albă	5,92	5,98	5,62	5,84	2,19	***
Coarnă neagră	4,32	4,93	4,4	4,55	0,9	**
Coarnă vânătă	4,6	5,11	4,36	4,69	1,04	**
Conic auriu	3,5	3,91	3,37	3,59	-0,06	-
Moldovel	5,53	5,94	5,68	5,72	2,07	***
Negru crocant de Buziaş	4,42	4,84	4,43	4,56	0,91	**
Ochiul boului	4,85	5,23	4,89	4,99	1,34	***
Răşchirată albă	4,71	5,33	4,84	4,96	1,31	***
Roşu crocant de Silagiu	3,27	3,4	3,23	3,3	-0,35	-
Ţâţa caprei albă	4,02	4,7	4,73	4,48	0,83	**
Ţâţa caprei neagră	3,53	3,73	3,77	3,68	0,03	-
Ţâţa vacii	4,24	4,48	4,13	4,28	0,63	*
Chasselas dorė (MT)	3,54	3,81	3,61	3,65	-	-

DL5% 0,42   DL 1% 0,74   DL0,1% 1,16

Values below the witness, but statistically uninsured had the following varieties: Auriu de Silagiu, Roşu crocant, Conic auriu, and higher values than witness and statistically ensured had varieties: Alb lax de Silagiu, Coarnă albă, Moldovel, Ochiul boului, Răşchirată albă, Coarnă vânătă, Coarnă neagră, Negru crocant de Buziaş, Ţâţa capreialbă and Ţâţa vacii.

In terms of production / vine, low values of regression coefficient indicating a high static stability were observed in biotypes: Alb lax de Silagiu, Ochiul boului, Auriu de Silagiu, Ţâţa capreineagră, which are carrying constant values of this trait over the whole experiment period.

Different values of production / vine from year to year during the period 2008-2010, namely a static instability of this trait have been emphasized in varieties: Coarnă albă, Conic auriu, Ţâţa capreialbă, Ţâţa vacii.

The lowest values of genotype *x* environment interaction associated with a regression coefficient close to the unity were observed for varieties: Chasselas dore, Negru crocant de Buziaş, Moldovel, Coarnă neagră, Coarnă vânătă which emphasizes a high dynamic stability that allows them to achieve a parallel value of production with the average of other varieties from the experience.

In varieties: Ţâţa capreineagră, Coarnă albă, Conic auriu, this trait has a pronounced dynamic instability, the production values not being correlated with the favorability experimental conditions in 2008-2010 period.

Table 3: Stability of the yield/hub through Finlay and Wilkinson [7] linear regression for the table varieties studied during 2008-2010.

	Variety	**Mean (kg)**	**Regression coefficient**	**Stability type I (rank)**	**Stability type II (rank)**	**Regression constant**	**Residual variance**	**Stability type III (rank)**
1	Alb crocant de Buziaş	2,46	0,642	5	6	0,86	0,001	2
2	Alb lax de Silagiu	2,04	0,094	1	13	1,80	0,006	5,5
3	Auriu de Silagiu	1,62	0,264	3	11	0,97	0,025	9
4	Coarnăalbă	3,37	2,097	16	15	-1,85	0,255	15
5	Coarnăneagră	3,09	0,791	6	4	1,12	0,080	12
6	Coarnăvânătă	3,50	1,285	10	5	0,31	0,352	16
7	Conic auriu	2,59	2,071	15	14	-2,56	0,009	7
8	Moldovel	2,18	0,904	7	3	-0,66	0,031	10
9	Negrucrocant de Buziaş	2,47	0,943	8	2	0,12	0,001	2
10	Ochiulboului	2,33	0,232	2	12	1,75	0,083	13
11	Răşchiratăalbă	2,99	1,487	12	8	-0,71	0,001	2
12	Roşucrocant de Silagiu	2,15	1,395	11	7	-1,32	0,034	11
13	Ţâţacapreialbă	2,53	1,655	14	10	-1,59	0,128	14
14	Ţâţacapreineagră	2,12	-0,437	4	16	3,21	0,006	5,5
15	Ţâţavacii	2,17	1,542	13	9	-1,67	0,002	4
16	Chasselasdorė	2,20	1,035	9	1	0,37	0,011	8

The highest stability of type III, the minimum values of deviations among the average productions/vine towards the linear regression respectively, was observed in Alb crocant de Buziaş, Negru crocant de Buziaş and Răschiratăalbă varieties (Table 3).

Table 4: The components of linear regression variance, according Hardwick and Wood [8], for yield/hubin the table varieties studied during 2008-2010.

Variability source	SP	GL	S^2 (SP/GL)	F Test
Total	13,638	47		
Varieties	11,784	15	0,785	**F=11,50****
Years	0,557	2	0,279	**F=4,08***
Varieties x Years	1,296	30	0,043	**F=0,63**
Regression heterogeneity	0,270	15	0,018	**F=0,26**
Error	**1,025**	**15**	**0,068**	

Also in Coarnăvânătă, Coarnă albă and Ţâţa capreialbă varieties, which are showing a type III low stability, production values during the experimental period show large deviations from linear regression.

As data shown in Table 5, having in view the insignificant *F* test for heterogeneity of regression (Table 4), it appears that the regression model is suitable for studying the stability of this trait and estimates properly the performance for table grape varieties studied in 2008-2010 period. Also, it is noted that there are significant differences among both species and the three years of experience in terms of the average values of the yield/vine.

As shown in Table 6, it is observed that the higher stability of yield /vine in the experimental period, low values and significant ecological valence respectively, presents varieties: Negru crocant de Buziaş, Alb crocant de Buziaş, Răşchirată albă, Roşu crocant de Silagiu.

A great instability of respective trait attested by the high values of ecological valence was observed in: Coarnă vânătă, Coarnă albă, Ţâţa capreialbă, Ochiul boului. Analysis of genotype x environment interaction, show that the higher stability of the trait, namely genotype x environment interaction (less than 4% of the total) presents varieties: Negru crocant de Buziaş (3,15 %); Alb crocant de Buziaş (3,30 %); Răşchirată albă (3,48 %), Chasselas dore (3,57%).

A high genotype x environment interaction (above 10%) associated with a high instability of yield / vine was observed in: Coarnă vânătă (16,83 %) and Coarnă albă (14,58%). For production values / vine in the experimental period 66.92% of genotype *x* environment interaction is due to imperfect correlations, so that in assessing the stability of different varieties of table grape, imperfect correlations have a significant involvement.

Table 5: Stability of the yield/hub through Wrike [8] ecological valence in the table varieties studied during 2008-2010.

No.	Variety	Mean	Ecological valence	Ecological valence variance	F Test	Stability rank
1	Alb crocantBuziaş	2,46	0,005	0,007	153,91**	2
2	Alb lax de Silagiu	2,04	0,035	0,003	0,05	8
3	Auriu de Silagiu	1,62	0,044	0,014	0,10	9
4	Coarnă albă	3,37	0,297	0,204	0,60	15
5	Coarnă neagră	3,09	0,082	0,051	0,27	12
6	Coarnă vânătă	3,50	0,355	0,205	0,16	16
7	Conic auriu	2,59	0,049	0,079	16,08**	10
8	Moldovel	2,18	0,031	0,029	0,93	7
9	Negru crocantBuziaş	2,47	0,001	0,016	74,10**	1
10	Ochiul boului	2,33	0,103	0,042	0,02	13
11	Răşchirată albă	2,99	0,009	0,039	75,02**	3
12	Roşu crocantSilagiu	2,15	0,039	0,051	2,01	4
13	Ţâţa capreialbă	2,53	0,143	0,112	0,75	14
14	Ţâţa capreineagră	2,12	0,078	0,006	0,99	11
15	Ţâţa vacii	2,17	0,013	0,043	32,92**	6
16	Chasselas dorė	2,20	0,011	0,024	3,26	5

Table 6: Stability of the yield/hub through (Muir et al [10]) heterogeneous variances (HV) and imperfect correlations (IC) in the table varieties studied during 2008-2010.

No	Variety	Mean	SP		SP		SP	
		(kg)	(HV)	(%)	(IC)	(%)	(GE)	(%)
1	Alb crocantBuziaş	2,46	0,029	6,83	0,013	1,56	0,043	**3,30**
2	Alb lax de Silagiu	2,04	0,037	8,67	0,021	2,39	0,058	**4,47**
3	Auriu de Silagiu	1,62	0,022	5,20	0,040	4,62	0,062	**4,81**
4	Coarnă albă	3,37	0,071	16,64	0,117	13,56	0,189	**14,58**
5	Coarnă neagră	3,09	0,014	3,18	0,068	7,81	0,081	**6,28**
6	Coarnă vânătă	3,50	0,072	16,75	0,146	16,87	0,218	**16,83**
7	Conic auriu	2,59	0,018	4,29	0,047	5,39	0,065	**5,03**
8	Moldovel	2,18	0,015	3,48	0,041	4,74	0,045	**4,32**
9	Negru crocantBuziaş	2,47	0,021	4,84	0,020	2,31	0,041	**3,15**
10	Ochiul boului	2,33	0,013	3,13	0,079	9,09	0,092	**7,12**
11	Răşchirată albă	2,99	0,014	3,17	0,031	3,64	0,045	**3,48**
12	Roşu crocant de Silagiu	2,15	0,014	3,17	0,046	5,36	0,060	**4,64**
13	Ţâţa capreialbă	2,53	0,028	6,67	0,083	9,62	0,112	**8,64**
14	Ţâţa capreineagră	2,12	0,030	7,02	0,049	5,74	0,079	**6,16**
15	Ţâţa vacii	2,17	0,013	3,13	0,033	3,86	0,047	**3,62**
16	Chasselas dorė	2,20	0,016	3,83	0,030	3,44	0,046	**3,57**
Total			**0,427**	**33,08**	**0,864**	**66,92**	**1,283**	**100,00**

Given the imperfect correlation is observed that the most stable values of this trait were recorded by varieties: Alb crocant de Buziaş, Negru crocant de Buziaş, Alb lax de Silagiu, Chasselas dore, Răşchirată albă, which had a consistency of order rank for yields over the experimental period , under a low genotype x environment interaction.

Coarnăvânătă and Coarnă albă varieties presented in this case high values of the deviations among order rank corresponding to the yields from the experimental period.

During experimentation significant *F* test values of stability variance analysis table (Table 6) indicates that there were significant differences in terms of climatic conditions regarding yields / vine achieved by table grape varieties.

Low variance during the experimental period for this trait have been performed by varieties: Alb crocant de Buziaş, Negru crocant de Buziaş, Chasselasdore, Răşchirată albă, which are showing a high stability of yield / vine in the climatic conditions of experimental years, while in Coarnă vânătă, Coarnă albă and Răşchirată albă varieties is observed a high variance in yield / vine associated with reduced stability.

Considering the low and insignificant values of *F* test (Table 7) for heterogeneity regression, shows that the regression model used to estimate the stability of the yield/vine is suitable for this study and allows to obtain meaningful results on the table grape varieties tested in 2008–2010 period.

Table 7: Variance components (Shukla [11]) for the stability of the yield/hub in the red wine varieties studied during 2008-2010.

Variability source	SP	GL	S^2 (SP/GL)	F Test	Stability rank
Varieties	11,784	15	0,786	11,50**	
Years	0,557	2	0,279	4,08*	
Varieties x Years	1,296	30	0,043	0,63	
Alb crocant de Buziaş			0,001	0,01	1
Alb lax de Silagiu			0,017	0,25	6
Auriu de Silagiu			0,022	0,32	9
Coarnă albă			0,166	2,44	15
Coarnă neagră			0,044	0,64	12
Coarnă vânătă			0,199	2,93	16
Conic auriu			0,025	0,37	10
Moldovel			0,015	0,21	7
Negru crocant de Buziaş			0,002	0,04	2,5
Ochiul boului			0,056	0,82	13
Răşchirată albă			0,002	0,03	2,5
Roşu crocant de Silagiu			0,019	0,28	8
Ţâţa capreialbă			0,078	1,15	14
Ţâţa capreineagră			0,042	0,61	11
Ţâţa vacii			0,004	0,06	5
Chasselas dorė			0,003	0,05	4

Low values of regression variance which certifies a high stability of the trait in the experimental period were observed in the varieties: Alb lax de Silagiu, Ţâţa vacii, Ţâţa capreineagră, Alb crocant de Silagiu, Răşchirată albă.

Table 8: Analysis of regression heterogeneity (Shukla [11]) for the yield/hub in the table varieties studied during 2008-2010.

Variability source	SP	GL	S^2 (SP/GL)	F Test	Stability rank
Regression heterogeneity	0,270	15	0,018	0,27	
Balance	1,025	15	0,068	1,00	
Variety x Years	1,296	30	0,043	0,63	
Alb crocant de Buziaş			0,005	0,07	6
Alb lax de Silagiu			0,002	0,03	1,5
Auriu de Silagiu			0,023	0,34	9
Coarnă albă			0,286	4,19**	15
Coarnă neagră			0,087	1,27	12
Coarnă vânătă			0,398	5,83**	16
Conic auriu			0,006	0,08	7
Moldovel			0,030	0,44	10
Negru crocant de Buziaş			0,004	0,06	4,5
Ochiul boului			0,090	1,32	13
Răşchirată albă			0,004	0,05	4,5
Roşu crocant de Silagiu			0,034	0,49	11
Ţâţa capreialbă			0,141	2,07	14
Ţâţa capreineagră			0,003	0,04	3
Ţâţa vacii			0,002	0,03	1,5
Chasselas dorė			0,008	0,12	8

An emphasized instability due to a significant influence of genotype *x* environment interaction in the expression of this trait was found in varieties: Coarnăvânătă, Coarnăalbă and Ţâţacapreialbă. It is noted that there is a very close concordance among the results of the six models for assessing the stability of the yield / vine in those 16 table grape varieties. According to the results of the six models it results that the highest stability of this trait in experimental period presents varieties: Negrucrocant de Buziaş, Alb crocant de Buziaş, Răşchiratăalbă, Chasselasdore, Alb lax de Silagiu.

A strong instability correlated with a high influence of genotype x environment interaction in the expression of yield / vine was noted in the varieties: Coarnăalbă, Ţâţacapreialbă, CoarnăVânătă.

4. CONCLUSIONS

The western area of Romania stands out through its abundance of local varieties and biotypes, some really valuable, which most of them are very little known, perhaps only of those in whose household are found.

• Varieties and local biotypes from Buziaş-Silagiu area, represents a valuable genetic heritage, because of their productive and quality traits, and also for biological resistance, they are both a source of authenticity and uniqueness and a source of variability, of ancestry, in the improvement of the grapevine.

• Table grape varieties Chasselas dore, Negru crocant de Buziaş, Auriu de Silagiu, Ochiul boului, Moldovel, Ţâţa capreineagră, showed a high stability associated with a lower average bunch weight compared with the mean of experience. At the same time in the Ochiul boului variety the higher stability is associated with high levels of this trait above the average of the experience. Răşchirată albă and Coarnă vânătă varieties that perform above average values of this trait towards the average of the experience strongly controlled by genotype x environment interaction, shows a specific adaptability to favorable climatic conditions.

• In table grape varieties was recorded the highest stability of yield/vine associated with below average levels of experience. The white varieties Coarnă albă and Conic auriu, yield instability is associated with higher average values of this trait towards the average of the experience, as a result of specific adaptations to favorable environmental conditions.

• From these varieties and local biotypes, we recommend due to their valuable traits to be tested in varietal assortments the following: Auriu de Silagiu, Alb crocant de Buziaş, Negru crocant de Buziaş from varieties for fresh consumption group.

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MODELING THE LATERAL UNIFORMITY OF WHEAT SEEDING

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Abstract. *Sowing units represent complex mechanical and pneumatic systems exposed to various stochastic disturbances. They have an important role in the technological process of wheat production. Under regular conditions, sowing operation should place the seed in rows at desired span, depth and seed to seed spacing, as well as to properly cover the seeds with soil and provide proper seed compaction. Depending on the crop species and agro-climatic conditions, recommended seeding parameters (row to row spacing, seed rate, seed to seed spacing, and depth of seed placement) may differ significantly. Sowing of small grain crops, such as wheat, barley, or oats, is most commonly done by seed drills, what imposed this kind of machines in the focus of interest of present paper. Imperfectness of seeding operation can decrease the crop yield and increase the consumption of seed over the minimum quantity that was actually needed for optimal crop growing. To enhance its quality and efficiency, the seeding process has to be carefully planned, accurately controlled and final seeding results have to be evaluated. Therefore, this paper presents an original mathematical model based upon the formerly reported experimental results, as well as own experimental study dealing with the lateral distribution of wheat seeds after machine seeding. Differential equation, accompanied with the specific appropriate additional conditions, which describes lateral distribution of wheat seeds after machine seeding, has been formulated and presented. Developed model was experimentally tested. It has been demonstrated that proposed differential equation has an analytical solution in the form of the normal Gaussian distribution function, which tightly follows the lateral distribution of wheat plants seeds after their seeding with pneumatic drill seeder.*

Key words: *mathematical model, wheat, seed distribution, partial differential equation, stochastic disturbances*

1. INTRODUCTION

The main technological goal of sowing operation is to place the seed of specified plant in straight rows at desired depth, to provide optimal longitudinal (intra-row/travel direction) and lateral (inter-row) seed to seed spacing, to adequately cover the seeds with soil and provide proper compaction of seed. The recommended inter-row spacing, depth of seed placement, seed to seed spacing within a row, and seed rate may vary depending on the crop and agro-climatic conditions.

Inadequate sowing methods, as well as some different factors like: soil tillage, soil moisture, quality of sowing machine and its condition introduce the following limitations:

1. It is impossible to achieve uniform seed distribution. Although a farmer may sow at desired seed rate, inter-row and intra-row distribution of seeds is likely to be uneven, resulting in bunching and gaps in the seeded field.
2. Poor depth control of seed placement. Placement of seeds at uneven depth may affect plant emergence, i.e. result in poor emergence.
3. It is necessary to sow at high seed rates and, later on, to bring the plant population to desired density level by thinning.
4. High requirement for labor, because additional workers are needed for dropping seed in soil again.
5. The influence of inaccurate seed positioning on plant stand is stronger in situations when crops are sown under dry farming conditions.

Sowing of small grain crops, like wheat that has been analysed in present study, as well as barley or oats, is done by seed drills. Consequently, seed drill machine operation was in the focus of interest of present study and has been analysed in details. Machines of this kind meter out and put continuous fine stream of grain seeds in the soil, with respect to the particular demands of a wide crops variety. Inappropriate control of this process most commonly decreases the crop yield or increases the seed consumption with respect to those that was actually needed to grow the crop, because many of the seeds failed to grow due to lack of adequate contact with moisture and soil [1].

2. MATERIAL AND METHODS

The experimental part of this study has been performed in 2011 at the "PKB" Corporation – Belgrade, Serbia. The parcel T-10 of the farm "Mladost", Jabučki Rit - Belgrade, having surface area of 70 ha is located at the GPS coordinates (44^o 55' N, 20^o 33' E). The soil, classified as Humogley, following the FAO/UNESCO rules, contained 41% sand, 26% silt, 33% clay and 4.1% organic matter. Total precipitation after sowing operation in this area was 94 mm.

Before sowing, shallow moldboard ploughing, chisel ploughing, two subsequent disc harrowing and seedbed preparation have been performed. There were no rocks, hard clay clods and crop residue in the soil of the experimental parcel. The maize crop was grown on the experimental land prior to the wheat seeding.

Fig. 1: Pneumatic seed drill IMT 634.16 in field operation.

The seeding machine IMT 634.16, made by “Industry of Motors and Tractors” – Belgrade-Serbia, shown in Fig. 1, was tested with wheat seed "Renesansa" (made by ”NS Seme”, Serbia). The number of seeds per linear meter of furrow, the uniformity of lateral distribution of seeds placement were measured and analysed.

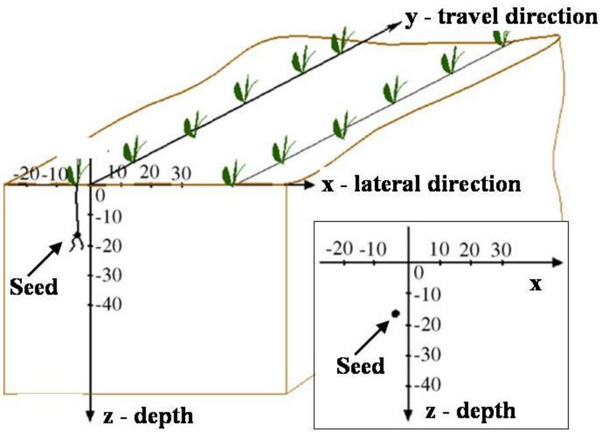

Fig. 2: Reference Descartes coordinate system. Adapted from [2].

This seed drill has been specifically designed for machine handling of various types of grains and grass seeds, such as winter and spring wheat, rye, barley, oats, alfalfa olaceous beet, sweet vetch, etc. Grain seeding at desired rates is controlled by variator. A seeding unit with fluted rollers ensures accurate metering of various seeds. Grain is delivered to coulters by means of pneumatic air stream within delivery houses.

To enable statistical analysis and mathematical modeling, the reference Oxyz coordinate system, presented in Fig. 2, is adopted following [2].

Besides the calculation of descriptive statistical parameters, it is a common technical practice to analyse the probability distribution of statistical variable of interest. To achieve this goal, in addition to empirical frequency

$$[(x_j, f_{x_j});\ j = 1,2,...m_x] \tag{1}$$

related to transversal (lateral direction x) seed distribution, the analogue probability density function (shortly denoted as *pdf* in further text) is used in this study:

$$pdf\left(x_j\right) = \frac{f_{x_j}}{\Delta x} \cdot 100\ [\%/\text{mm}],\ \ (j = 1, 2,..., m_x). \tag{2}$$

This way, the experimental fitting "points" of probability density function of a stochastic variable (lateral seed spacing x, Fig. 2) has been prepared. Finally, these points (*pdf* values) are fitted following the least-squares fitting method to adjust the parameter values. More details can be found in [3] and [4], among many others. All computations are performed using the software package – R [5] and Microsoft EXCEL.

Various model functions were tested toward the empirical points. Acceptable results are achieved by normal Gaussian function

$$y = y_0 + \frac{A}{\sqrt{\frac{\pi}{2}} \cdot w} \cdot e^{(-2)\cdot \frac{(x-x_c)^2}{w^2}}. \tag{3}$$

In the Eq. 3, y represents dependent variable *pdf(x)*, while x represents independent variable (lateral seed separation x). At the same time, y_0, x_c and w are the fitting parameters that are evaluated by the least-square method.

3. THEORETICAL RESULTS – THE MATHEMATICAL MODEL

The problem in this paper can be described by the diffusion equation of the form

$$\frac{\partial y}{\partial t} = \frac{w^2}{8} \frac{\partial^2 y}{\partial x^2}, \tag{4}$$

where $y = y(x,t)$ is a function which describes the height of the structural elements x and $t > 0$ are the coordinates of space and time, respectively, and w is a known constant. As it is known [6], the solution of equation (4) is of the form

$$y(x,t) = t^{-\alpha}\ f\left[(x - x_c)t^{-\alpha}\right] \tag{5}$$

where $f(x)$ has the form

$$f(x) = B\ e^{-g(x)}. \tag{6}$$

α respectively $g(x)$ represent an unknown constant and respectively an unknown function. Furthermore $g(x_c) = 0$. The scaling condition is

$$g\left(xt^{-\alpha}\right) = g(x)t^{-1}. \qquad (7)$$

The constant B can be decided by the normalization condition

$$B\int_{-\infty}^{+\infty} e^{-g(x)}\,dx = 1. \qquad (8)$$

Thus, $y(x,t)$ can be written in the form

$$y(x,t) = Bt^{-\alpha}\,e^{-g(x)t^{-1}}. \qquad (9)$$

Substituting equation (9) into equation (4) implies

$$tg'' - g'^2 + \frac{8}{w^2}g = \frac{8\alpha}{w^2}t,\ \ g = g(x). \qquad (10)$$

The coefficients of the nonlinear equation (10) are analytic functions at $x = x_c$. So all solutions $g(x)$ are analytic at $x = x_c$ and can be represented by

$$g(x) = c_o + \sum_{n=1}^{\infty} c_n (x - x_c)^n. \qquad (11)$$

The condition $g(x_c)$=0 implies c_o=0. The nonlinear term g'^2 in (10) can be determined by the Cauchy product. Substituting (11) in (10) and comparison the coefficients of $(x - x_c)^n$ t, $n \geq 1$ yield

$$c_2 = \frac{4\alpha}{w^2} \quad \text{and} \quad c_n = 0,\ n \geq 3. \qquad (12)$$

Comparing the coefficients of $(x - x_c)^n$, $n \geq 0$ gives the recursion formula

$$\sum_{k=0}^{n} (k+1)(n-k+1)c_{k+1}\,c_{n-k+1} - \frac{8}{w^2}c_n = 0. \qquad (13)$$

Using c_0=0 in (13) with n = 0 gives c_1 = 0. So, (13) with n = 1 is satisfied. Coefficient c_2 can be calculated by (13) with n = 2. Thus,

$$c_1 = 0,\ \ c_2 = \frac{2}{w^2} \quad \text{and } c_n = 0,\ \ n \geq 3. \qquad (14)$$

Equating c_2 in (12) and c_2 in (14) gives $\alpha = \frac{1}{2}$. Inserting c_o = 0 and (14) in (11) gives

$$g(x) = \frac{2}{w^2}\ (x - x_c)^2. \qquad (15)$$

The solution (9) of (4) is

$$y(x,t) = Bt^{-\frac{1}{2}} e^{-\frac{2(x-x_c)^2}{w^2 t}} \quad , \quad t > 0 \,. \tag{16}$$

Inserting (15) in (8) gives the normalisation factor

$$B = \frac{1}{w}\sqrt{\frac{2}{\pi}} \,. \tag{17}$$

Inserting (17) in (16) implies the complete solution of (4), that is

$$y(x,t) = \frac{1}{w\sqrt{\frac{\pi}{2}}} \; t^{-\frac{1}{2}} e^{-\frac{2(x-x_c)^2}{w^2 t}} \,. \tag{18}$$

4. EXPERIMENTAL RESULTS AND VERIFICATION OF THE MATHEMATICAL MODEL

Empirical *pdf*, calculated on the base of experimental data, are shown in Fig. 3. The shape of this chart indicates that lateral wheat seed distribution follows the well known Gaussian normal distribution function (3).

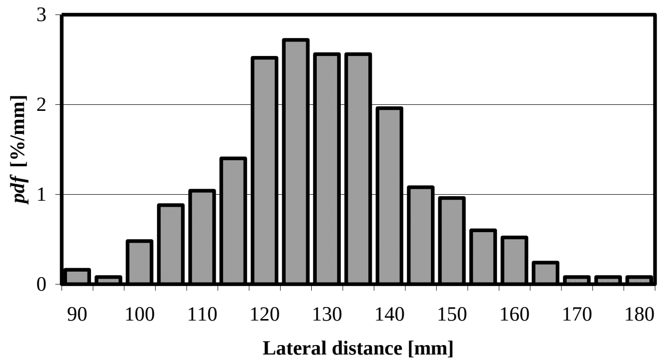

Fig. 3: Probability density function (*pdf*) of lateral wheat seed distribution.

In order to additionally check this conclusion, descriptive statistical parameters of raw experimental data distribution were calculated and presented in Table 1. Skewness and kurtosis factors having values of 0,26 and 0,19 respectively, are very close to zero value that characterizes skewness and kurtosis factors of the well known normal Gaussian distribution function.

Therefore, Gaussian model function was finally practically tested for approximation of *pdf* of lateral wheat seed distribution. The experimental data are presented together with fitted model function in the Fig. 4. As it was expected, results were quite good.

Table 1: Descriptive statistics.

Statistical parameter	**Symbol**	**Value**
Number of data	N [-]	500
Mean value	$\bar{x}$ [mm]	129,51
Lower 95% confidence level of the mean value	$L_{CL}(\bar{x})$ [mm]	128,14
Upper 95% confidence level of the mean value	$U_{CL}(\bar{x})$ [mm]	130,88
Median	Me_x [mm]	129,00
Minimum	x_{min} [mm]	89,00
Maximum	x_{max} [mm]	181,18
Amplitude interval (range)	A_x [mm]	92,18
The first 25% (lower) quartile	Q_{1x} [mm]	119,41
The third 75% (upper) quartile	Q_{3x} [mm]	138,48
The inter-quartile range	I_{QVx} [mm]	19,08
Percentile 10%	$x_{10\%}$ [mm]	110,00
Percentile 90%	$x_{90\%}$ [mm]	150,00
Variance	σ_x^2 [mm^2]	242,73
Standard deviation (σ)	σ_x [mm]	15,58
Lower 95% confidence level of σ	$L_{CL}(\sigma_x)$ [mm]	14,67
Upper 95% confidence level of σ	$U_{CL}(\sigma_x)$ [mm]	16,61
Variation coefficient C_V	C_{Vx} [%]	12,03
Standard error of C_V	[%]	0,70
Amplitude coefficient	C_{Ax} [%]	71,18
Interquartile coefficient	C_{IQVx} [%]	14,73
Skewness factor	S_x [-]	0,26
Std.err. of Skewness	[-]	0,11
Kurtosis	K_x [-]	0,19
Std.err. of Kurtosis	[-]	0,22
Flatness factor	F_x [-]	3,19
Std.err. of flatness factor	[-]	0,22

The coefficients of fitting function are given in Table 2, together with the parameters that characterize fitting accuracy. The so called R-square value is very high, over 0,97, while the root-mean-square error (or simply the standard error of estimate) was small, i.e. 0,166. This way, the applicability of Gaussian normal function for accurate approximating the lateral seed distribution has been successfully verified. In addition, the mathematical model based on partial differential equation presented in chapter 3, has been also experimentally verified.

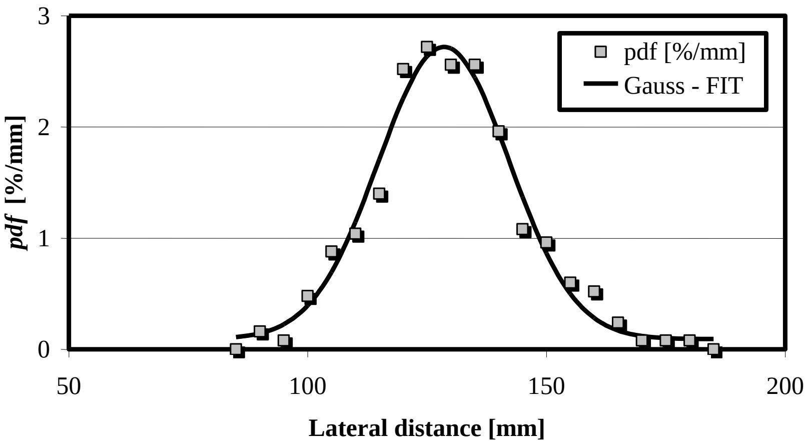

Fig. 4: Fitting of the probability density function of wheat seed distributions over width.

Table 2: Fitting parameters and accuracy.

	Normal FIT of lateral distribution
y_0	0,092457713
x_c	128,542186
w	27,41162362
A	90,32561263
R-Square	0,975
Adj. R-Square	0,970
Root-MSE (RMSE)	0,166

5. CONCLUSIONS

Contemporary sowing units represent complex mechanical and pneumatic systems exposed to a wide variety of stochastic disturbances. In order to achieve optimal performances, their condition, maintenance and operation have to be carefully observed, and controlled. To achieve these goals, the experimental research approach should be combined with mathematical modeling of the processes and operations of interest.

Following the common practice, in present paper is presented a partial differential equation model describing the *pdf* of lateral distances of wheat seeds after machine seeding. The model has been experimentally verified and explicit analytical form of *pdf* was established. The basic goal of approximating an experimentally determined *pdf* with an analytic function having appropriate shape is to describe a large amount of empirical data (represented by empirical statistical distribution), with just a few parameters. These parameters are constants (coefficients) in the adopted *pdf* model function, which has to be evaluated through some kind of a suitable fitting procedure.

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Case study

SPATIAL ANALYSIS (GIS) AS A TOOL FOR TIMBER EXTRACTION AND FOREST MANAGEMENT OPTIMIZATION. A STUDY CASE IN BASILICATA REGION, SOUTH ITALY

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Abstract. *ArcGIS software was used for timber harvesting planning in five (5) different mountainous broadleaf forest areas from Basilicata region, located in South Italy. Orographic characteristics, such as slope, watershed systems features, hydrogeological risk and other natural obstacles (accidental nature of ground) were considered. The different manual and mechanical timber extraction and concentration methods used by local timber companies were also considered. The different typologies of roads network to access forests were also introduced in the models.*
The analysis allowed identifying forest areas with territorial constraints and orographic restrictions, and with different accessibility, for a new planning of additional roads necessary for timber extraction optimization, as well as optimized site-by-site timber extraction methods. This methodological approach should be tested in other mountainous forest regions.

Key words*: timber harvest, GIS, forest accessibility, new forest road construction, territorial constraints*

1. INTRODUCTION

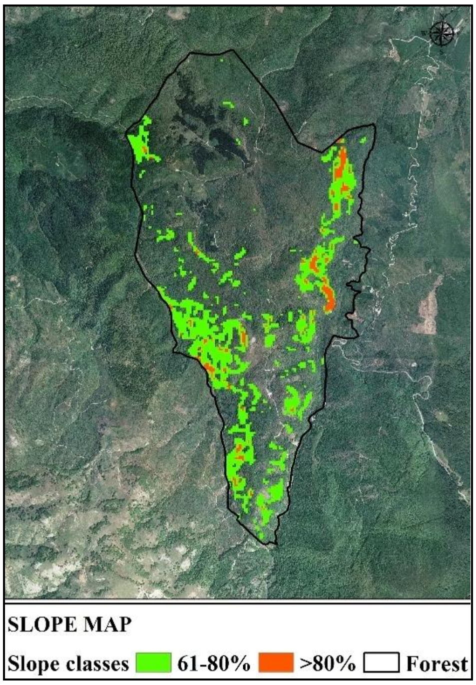
The GIS is a software technology that allows you to locate and analyze objects and events that occur on the earth, while the Italian SIT (Territorial information system) is a set of hardware technology components, software and human resources capable to process, store, analyze and integrate spatial data to produce information for the government and management of the territory [7]. There are various software technologies used based on GIS, as well as experiences within forestry sciences based on the management of digital territorial data [10] that were used to access road infrastructure network in the forest [12].

By combining and analyzing information from orographic type, territorial constraints, and infrastructure network, cartographic models of analysis can be processed aimed to identify, site by site in the forest, the labor instruments and the work systems more rational in relationship to the land conformation (territorial restrictions) and the network road features.

The main goal of this study is to optimize the timber extraction in Apennine mountainous areas with the aid of geographic information systems (GIS). This approach was developed for new road construction in timber extraction sector within five forested areas in the province of Potenza, Basilicata region, Italy.

2. Material and methods

The five studied forest areas are Regional Forests belonging to the province of Potenza, Basilicata region in South Italy: Bosco Grande Forest, Grancia Forest, Fossa Cupa Forest, Lata Forest, and Rifreddo Forest.



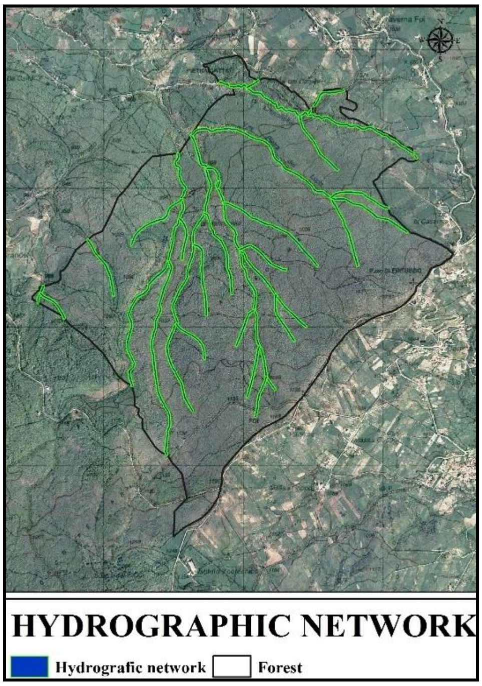


Fig. 1 (left): Example of slope classes calculated above 60%, in Fossa Cupa forest.

Fig. 2 (right): Example of hydrographic network in Bosco Grande forest.

In the forest utilization planning, the factors that define the choice of forest machines and labor instruments are mainly the road network, land features (slope and accessibility)

[8], territorial constraints (watershed systems features, hydrogeological risk) [9], timber dimensions, and lastly harvesting operations (harvesting systems and timber concentration systems).

2.1. Slope analysis

The slope analysis was performed using the DEM (Digital Elevation Model), and was then reclassified as percentage considering five classes according to Hippoliti [4]: 0-20%, 21-40%, 41-60%, 61-80% and > 80%. The high gradients influenced the new roads construction in forests, in fact land slopes above 60% were not considered for road construction, thus influencing the choice of timber harvesting and concentration systems, as shown in Fig. 1.

2.2 Hydrographic network analysis

This analysis focused on the rivers presence in the forests, and their influence on the timber harvesting operations and new roads construction, in the same five different wooded area of the Lucano Apennines.

A shape file has been constructed for determination of river surface incident on entire forest surface. The shape file was made by editing the hydrographic layer of Basilacata region government, and adding the rivers (seasonal river) not present on it, by digitizing over a map IGM 1:25.000 and the Ortophotos of Basilicata region, as shown in Fig. 2.

The river surface has been calculated building a buffer with 15 m width. This parameter is a measurement average of the rivers width with the aid of ArcGIS measurement tool, by photo interpretation.

2.3 Hydrogeological risk

The hydrogeological risk analysis was conducted using a reference layer downloaded from the website of Watershed Authority of Basilicata Region, [1]. The shape file was clipped for each forest, with Arcgis Geoprocessing Tool “Clip”, and then it was calculated its incident area on each forest.

The risk was classified in four classes according to Watershed Authority of Basilicata region [1], R1, R2, R3, and R4, as shown in Fig. 3.

The Hydrogeological risk classification is:

- **R1**= marginal damage environmental and cultural heritage;
- **R2**= minor damage to buildings, infrastructure and environmental heritage;
- **R3**= risk to the safety of people, functional damage to buildings, infrastructure, environment and cultural heritage, disruption of socio-economic activities;
- **R4**= loss of human life and / or serious injury to people, severe damage to buildings, infrastructure, environment and cultural heritage, destruction of socio-economic activities.

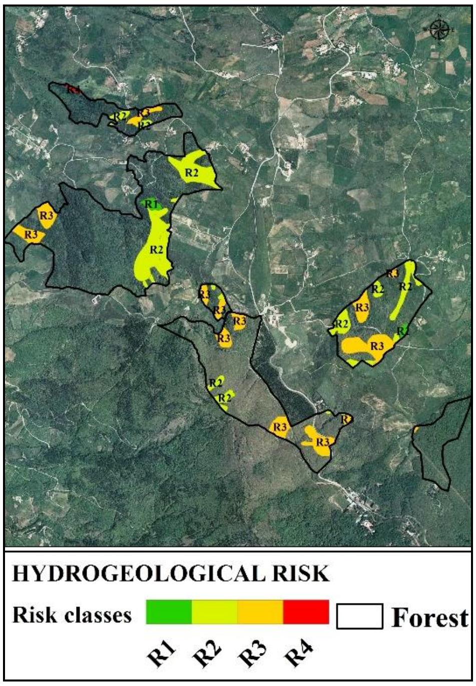


Fig. 3: Example of hydrogeological risk presence, in Rifreddo forest.

2.4 Roads network analysis

In the present study, it was proposed the development of a methodology to support the assessment of "timber harvesting road", in five different area of the Lucano Apennines, based on the determination of the uses in forested land and the determination of the wooded land served by roads.

Two shape files have been created for the determination of the roads already present in the forests, and the missing roads to be constructed, and were classified according to the classification of Hippoliti [4] as: main roads for truck, secondary roads for truck and roads for tractors or tracks. The first shape file was made by digitizing roads present in the forest, using a map IGM 1:25.000, traffic layer of the Environment Italian Ministry and Ortophotos of Basilicata region. Each road was classified according to the geometric features of Hippoliti classification such as minimum, maximum and average width, average and maximum slope, and curvature radius, which were recorded in Arcgis 10, [3], attribute table, as shown in Fig. 4.

The second shape file was built by digitizing along the contour lines, with 25 meters distance, constructed from DEM, with 20 meters resolution. New roads have been digitized, starting from the intersection of the contour layer and the existing roads layer, taking into account spatial constraints, such as hydrographic network, steep slopes, hydrogeological risk, like shown in Fig. 4.

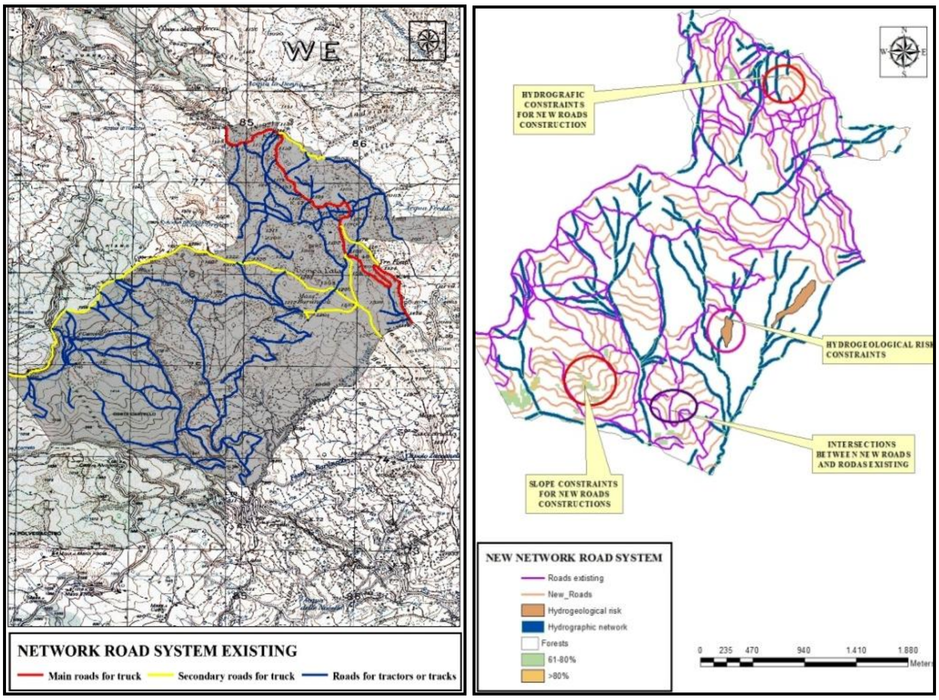


Fig. 4: Example of existing roads network (left) and new road system to be constructed (right) in Lata forest.

2.5 Timber volume

The timber volume was based on regional forest management plans. A pilot inventory was done considering six sampling plots for each of the 5 forests, which confirmed the timber data from forest management plans. In result, these forests have been subjected to low cutting intensities (low thinning and phytosanitary cuttings), according to the cutting intensity classification of Hippoliti [4], which provide a timber extraction up to 30 cubic meters per hectare for each extraction cycle. The trees diameter were very variable, depending on tree species and site conditions; usually the trees to be cut are chosen by a technician from regional forest, then marked, recorded, and in the end cut by the forest regional workers. This timber was used just for firewood, [11].

2.6 Timber concentration and harvesting systems

The scheme proposed by Hippoliti [4] takes into account several parameters, including slope classes, concentration system, cutting intensity, harvesting direction, timber dimensions, harvesting system. This was applied only in forests well served with roads, because the timber extraction cost was considered too high in areas without accessibility.

3. RESULTS AND DISCUSSION

3.1 Territorial constraint and orographic analysis

This analysis was made before the network road analysis, and allowed the identification of the areas having different territorial constraints within forests, that could influence on new road constructions.

The impact of each constraint is based on the percentage of the total area that it represents (Table 1).

Table 1: Territorial constraints effect in 5 forests of Basilicata region.

Forest Landform Morphographic Heterogeneity							
Forest	Forest area	Hydrographic network		Slope		Hydrogeological risk	
	ha	ha	%	ha	%	ha	%
Bosco Grande	472	30	7	0	0	8	2
Fossa Cupa	746	53	7	116	16	0	0
Grancia	456	22	5	0	0	22	5
Lata	755	52	7	11	2	5	1
Rifreddo	173	14	8	0	0	41	24

The results obtained from the spatial analysis showed that the hydrogeological risk is present, especially, in Rifreddo forest (41 ha, 22%) and in minor amount in Grancia forest (22 ha, 5%), while in other forests it is absent (Fossa Cupa forest) or present in minor amount. The analysis of the other two territorial constraints showed that slope constraint has a bigger impact in Fossa Cupa forest (116 ha, 22% area forest), while in other forests as a minor importance (Lata Forest) or is even absente.

Hydrographic network covers all the forests. The main problem that hydrographic network creates for the new road construction, it is not the total hectares, but its disposition in the forest, in fact, often it has a fan shape that covers almost the entire forest area, as shown in Fig. 2.

In fact, the forest managers need information about the potential impacts of roads on large areas to conduct cumulative effects analyses and watershed analyses for planning new road construction, and maintenance [5], [13].

The Fig. 5 shows the effect of territorial constraints on the new road construction proposal for the timber extraction. As it can be seen, in the blue circled area the negative effect of the constraints on a hypothetical road construction is shown, leaving a large area totally without roads. The main problem which the spatial analysis shows is the connexions of all constraints, which cover a good part of forest area.

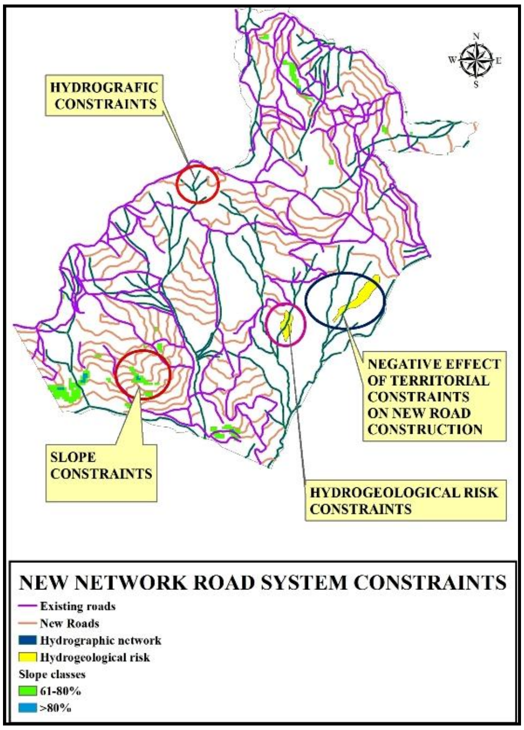


Fig. 5: Example of territorial constraints in Lata forest. Blue line limits an area with several constraints.

3.2 Network road system and harvesting operations analysis

The network road analysis was made after territorial constraints analysis to identify wooded areas in which could be possible building new roads for timber extraction.

The results obtained from the spatial analysis showed that the presence of roads in the forests in some areas was very poor. With the methodology proposed there was a significant percentage increase of new roads, and therefore a good increase of forest accessibility. In fact, the percentage increase of new roads on total was as follows: Bosco Grande Forest 56%, 48% Fossa Cupa Forest, Forest Grancia 63%, Lata Forest 49%, Rifreddo Forest 30%. The limited roads amount in some areas is due to the presence of territorial constraints, such as the hydrographic network, hydrogeological risk and steep slopes. The new road construction has allowed the increase of the road density, making forests more accessible. Adequate primary and secondary roads and trails should be planned with respect to density, routing and other physical characteristics such as width, slope and presence of suitable landings [2]. However, due to regional legislative constraints [6], we only proposed secondary roads or roads for tractors, and logically it is not advisable to build major roads in the forest already established. As shown in table 2.

Table 2: Proposal of new road construction intensity in 5 forests of Basilicata region.

New road construction influence										
Forest		Secondary road for truck				Road for tractors or track				Tot/Road
			before	**after**	**tot**		**before**	**after**	**tot**	
Name	ha	m	m/ha	m/ha	m/ha	m	m/ha	m/ha	m/ha	m
Bosco Grande	472	9431	2	20	22	12011	34	25	59	21442
Fossa Cupa	746	8533	12	11,4	23,4	22147	32	30	62	30608
Grancia	456	9536	5	21	26	17047	29	37	66	26583
Lata	755	10913	9	14,5	23,5	29695	46	39	85	40608
Rifreddo	173	1645	11	9	20	3066	49	17	66	4711

Table 2 shows as the new road construction has influenced the road density, especially the road for tractors or tracks. There have been considerable improvements of

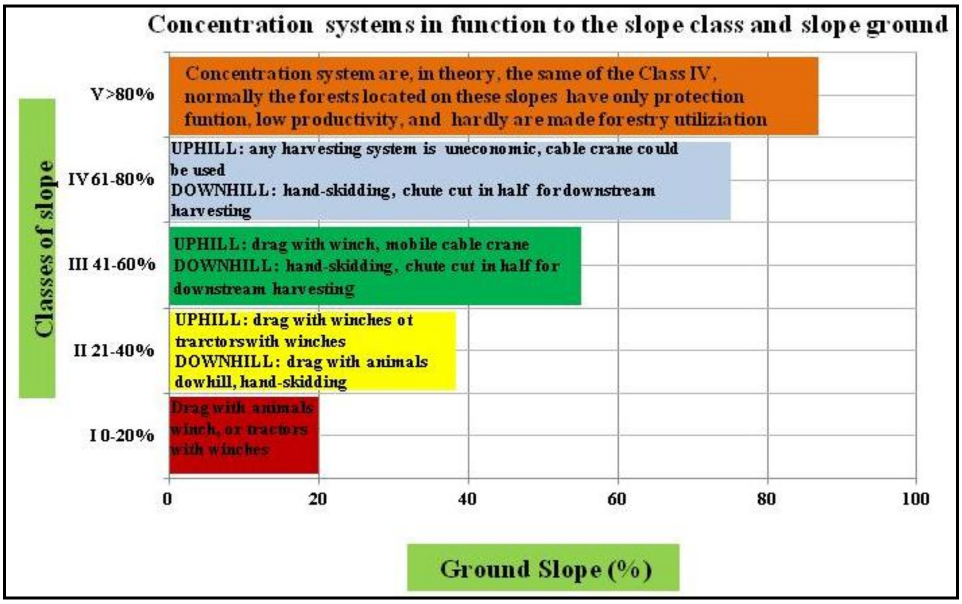


Fig. 6: Concentration systems in function to the slope class and ground slope.

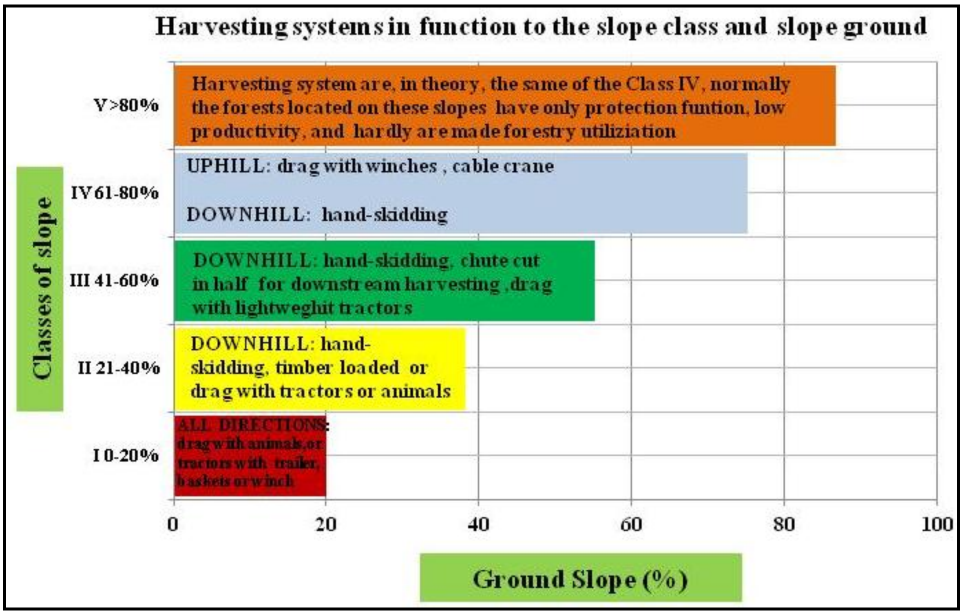


Fig. 7: Harvesting systems in function to the slope class and ground slope.

roads in the Grancia Forest, much less in the Rifreddo Forest, this difference was due to the strong hydrogeological risk presence on the territory of Rifreddo Forest. The choice for different roads was carried out considering the existing roads, and it was decided to build secondary roads where they were not present, connecting to previous secondary roads.

The choice of concentration and harvesting systems are resumed below in Figs. 6 and 7. In result, low cutting intensity were applied concerning timber diameter range from 17.5 cm to 24.0 cm, sometimes the diameter could be higher for some tree species and site conditions.

Hand-skidding, lightweight tractors with trailer, with basket or winch, drag with winches or with animals, are common systems used for timber concentration and harvesting in Basilicata region, these systems are used both downhill and uphill. Sometimes the forest companies used chute cut in half system, particular the system that consist of half chutes joined end-to-end to form a continuous channel guiding the timber down a slope. The cable crane system could be used within the two classes with high slope where the forests are served by roads, however on these high slopes all systems are usually uneconomic.

4. CONCLUSIONS

The proposed model has the goal to provide guidelines for the effective mechanization of forest harvesting and timber collection, directing the choice to the most suitable systems for different territorial conditions, in order to optimize the work of forest companies, for this reason it is desirable a prior spatial analysis, to improve forest planning (private or public), using advanced software systems, such as GIS tools.

The GIS spatial analysis could be a tool for the improvement and development of "woodcutter profession" still underdeveloped in the Basilicata region.

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Original scientific paper

MODELING THE TOMATO FRUIT GROWTH

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Abstract. *Developmental analysis of pericarp can predict fruit yield and quality in many crops, including tomato. Tomato fruit development in wild type, during late stage of cell division and cell expansion to ripe the fruit stage has been observed under controlled growing conditions. Detailed anatomical analysis of the pericarp indicates response of fruit developmental processes under optimal irrigation treatment. During fruit aging almost linear relationship between the increase of pericarp and mesocarp thickness has been verified. Simultaneously, exocarp and endocarp had slower growth and, consequently, lower impact on the total pericarp size. On the base of performed analysis, topographical maps showing relationships between the pericarp, exocarp, mesocarp and endocarp thickness against the fruit age and number of cell layers have been constructed. These kind of maps facilitate prognosis and control of tomato fruit growth and development during the production process.*

Key words: *pericarp thickness, cell layers number, interpolation, topographic map*

1. INTRODUCTION

For tomato and many other cultivated plants, as important for human nutrition and economy, the size of fruit is one of the key features of quality and yield, and the studies of fruit growth, at different levels, attracting a lot of attention of researchers [1]. More speciffically, prognosis and production control of tomato yield is also very important for agricultural managers, because it enables optimal dimensioning of the harvesting, transportation, storage and processing resources (agricultural mechanization, equipment, objects and workers needed).

Development of a fruit depends on the relationship between the process of cell division and cell growth. These two developmental phenomena, which are controlled by complex interactions between internal signals (due to effects of plant hormones) and external factors (the distribution of carbon, the impact of environmental factors, etc.), are important determinants of the essential criteria for quality of fruits, namely for the final fruit size and its parts [6].

Although the fruit is a complex organ that involve deep biochemical and physiological changing of their different structures (epidermal cells, pericarp, locular tissues and seeds), the pericarp structure was in focus in this study. Pericarp is subjected to different modification mechanisms that involve its own cells during all fruit developmental stages and ripening. Pericarp is composed from exocarp, mesocarp and endocarp. Outer layer of cells in the exocarp is epidermis and below there are two to three layers of hypodermal cells with thick cell walls. Epidermis hasn't stomata and has relatively thin cuticle, and the thickness of cuticle increases with the fruit growth. Mesocarp is made from large thin wall cells and vascular tissue. The aim of this study was modeling of tomato fruit growth, tested at the parameters of its parts thickness and construction of the appropriate topography maps.

2. MATERIAL AND METHODS

2.1. Growing conditions

Tomato plant (*Solanum lycopersicum* L.), cv. Ailsa Craig was raised from seed and transplanted into 20l pots (one plant per pot) filled with 11 kg of commercial compost (Potground H, Klasmann-Deilmann, Germany) in a growth chamber (photoperiod was 14h; light intensity at plant level 300 μmolm-2s-1, day/night temperature 25/18^{o}C and relative humidity 70%) at greenhouse conditions at Faculty of Agriculture (Fig. 1), University of Belgrade, during 2009 and 2010.

Fig. 1: Tomato plants under climatic chamber conditions.

After transplantation, all plants were irrigated daily to full pot holding capacity. Volumetric soil water content (θ) was 35% in that case. Ten days after transplantation, plants were subjected to full irrigation treatment, in which the whole root system was irrigated daily at 9:00 h to reach field capacity around 35%. The θ of both compartments of each pot was measured daily using TDR probes (time domain reflectometer, TRASE, Soil Moisture Equipment Corp., USA), on 20cm depth (Fig. 2).

Fig. 2: Young tomato plant in the irrigation treatment.

2.2. Cytological analysis of the pericarp section

In order to characterize the pericarp properties during fruit development, detailed cytological analyses were performed on different fruits in position of the third and fifth trusses starting at the 10th day after anthesis (daa) to the ripe fruit stage. Tomato fruits were harvested at 10 daa (corresponding to the phase of cell division), 15, 44 and 60 daa corresponding to the phase of cell expansion and ripening. Slides for light microscopy were made according to standard procedure [12]. Pericarp fragments from equatorial region were fixed in FAA (Formalin 5 ml, acetic acid 5 ml, and 90 ml 70 % ethyl alcohol) for 24h, postfixed in 70% ethanol and dehydrated in a graded ethanol series. After tissue impregnation in Histowax (56-58°C) samples were embedded. After cooling the blocks on a cold plate and solidifying in paraffin, histological sections of about 5–7 μm were cut using a microtome (Leica SM 2000 R). Before staining, the paraffin was removed from the sections by xylene, followed by rehydration in graded series of ethanol, and tissue was stained by safranine and alcian blue. Pericarp sections were observed with a Leica DMLS stereomicroscope and images were acquired with a Leica DC300 digital camera and measured with Leica IM 1000 software.

Two-dimensional interpolation [11] of acquired experimental data have been performed using the public domain “R” software [7], and “R” package “kriging” [8]. Finally, these calculated data were used for preparation of topographic maps representing relationships of thickness of different tomato skin layers (mesocarp, endocarp and exocarp) on the number of cell layers in the pericarp (nondimensional variable) and fruit age (days after anthesis – daa).

3. RESULTS AND DISCUSSION

Detailed analysis of pericarp development was performed in 20 lines of tomato plant on stage anthesis and ripe fruit [3], [2]. Tomato pericarp development during late cell division to ripe fruit stage was analysed in this study (Fig. 4). Pericarp thickness increased rapidly, due to cell division and consequently cells growth up to 15daa, while the secondary increase in pericarp thickness for more than 30% was observed during period of cell expansion to ripe stage. Similar developmental growth follows mesocarp, because mesocarp is most abundant tissue surround in pericarp, around 90-95%. Relative contribution of exocarp and mesocarp is minimal due to the small number of cell layers that makes it, up to 4 or 1, respectively for exocarp and endocarp.

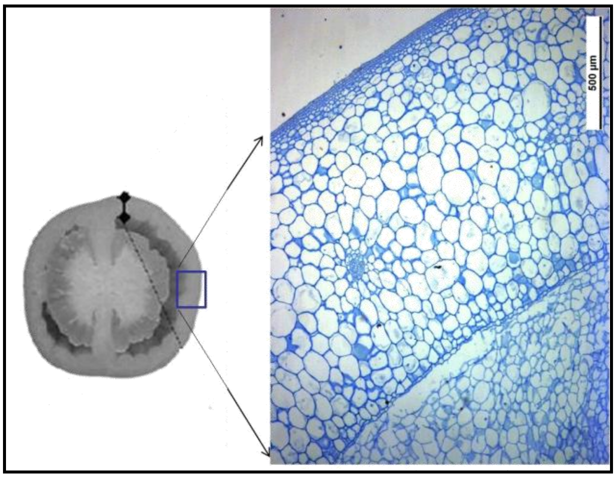
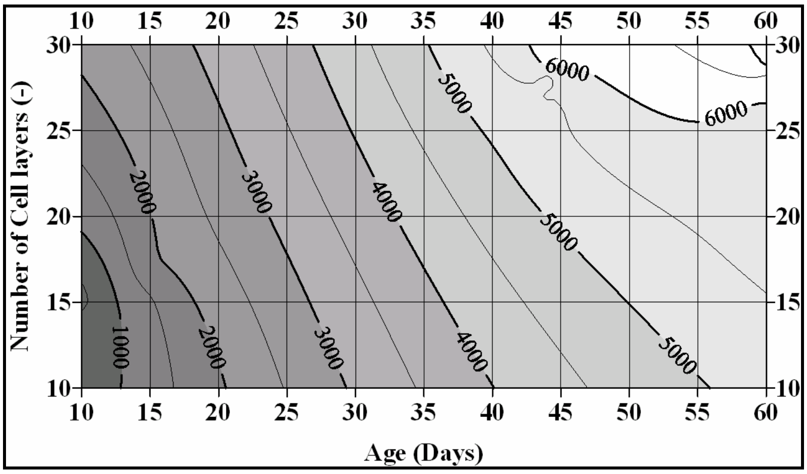


Fig. 3: Transversal sections of pericarp of wild type tomato fruit at 12 daa (left part of image indicated position of section on whole fruit) (bar = 500 µm).

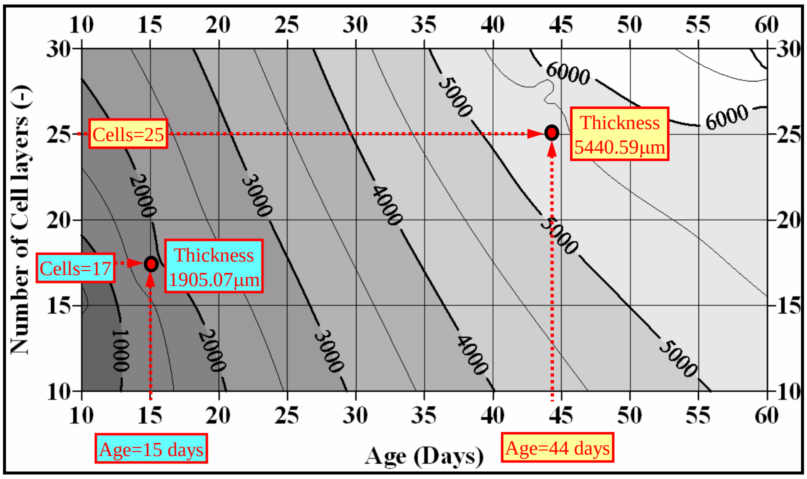
The number of pericarp cell layers at 3daa old fruit was 8,9, although [2] reported that cell layers numbers for anthesis stage. Newly formed cell layers were derived mainly from the outer subepidermal layer (outer mesocarp) and in lesser extend from inner subepidermal layer (inner mesocarp), as observed in study [2] by mitotic activity in both subepidermal layers. Mean number of pericarp cell layers in WT, FI treatment at ripe stage, was 27, although suggested that number could reach 28-30 cell layers at 14 days after fertilization, as depends on tomato genotype [3].

According to results from present study, it can be concluded that final cell layer formation didn't happen at the stage 6daa. This is in agreement with finding of [10], who found that period from 8-12daa still means cell division activity and report of [9] who suggested that mitotic activity starts decline after 10daa to maturity, similar as in our study. Except these so called histogenic cell division, randomly oriented cell division in pericarp happen to 20daa [2]. Histogenic cell division was described on pericarp *Vitis vinifera* thought presence of periclin cell division in outer epidermal layers [4].

Fig. 4 illustrates the relationship between the thickness of tomato pericarp (in µm) as dependent variable, against two independent variables: the tomato age (days after anthesis) and number of cell layers within the pericarp (non-dimensional value). This figure represents some kind of a topographic map, based on two-dimensional interpolation [11] and provides more detailed information on the interrelations between the three parameters of interest: tomato pericarp thickness, the fruit age and the number of cell layers for all possible values of these parameters in the tested ranges of variables of interest.



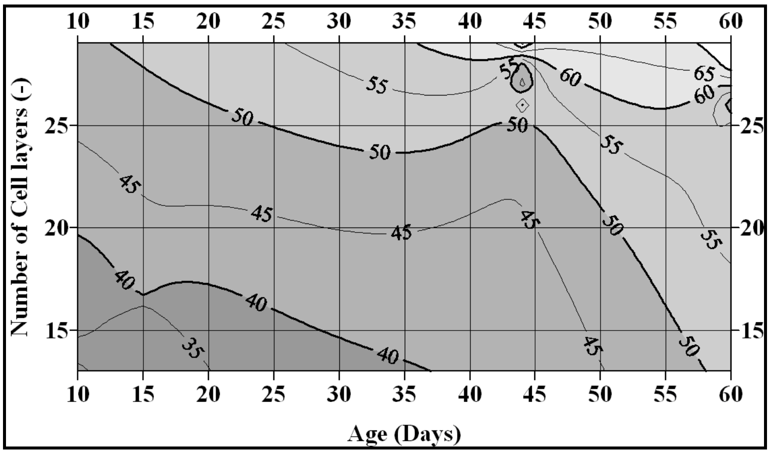
(a)



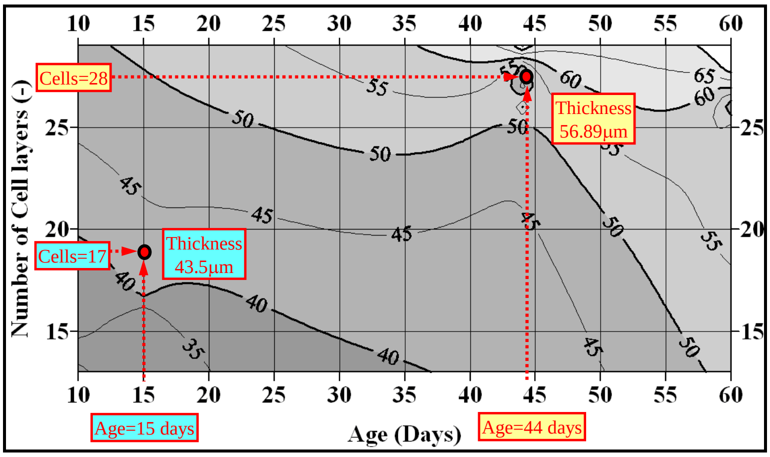
(b)

Fig. 4: (a) Dependency of pericarp thickness on the age and number of cells; (b) testing.

This map shows that pericarp thickness increases both with fruit aging and with increasing the number of cell layers in the pericarp. It has been tested in this study, as it is partially illustrated in Fig. 1b. The acquired pericarp sample at 15 (daa), possessing 17 cell layers had thickness of 1905,07 µm. This "point" falls just nearby the topographic isoline of 2000 µm, verifying the applicability of this map for estimation of the tomato pericarp thickness. In the same manner, tomato pericarp sample at 44 (daa), possessing 25 cell layers had thickness of 5440,59 µm. This experimental "point" falls close to the topographic isoline of 5500 µm, what is an additional confirmation of the map accuracy. This way, an applicability of the map in graphical describing the tomato pericarp thickness has been verified.



(a)

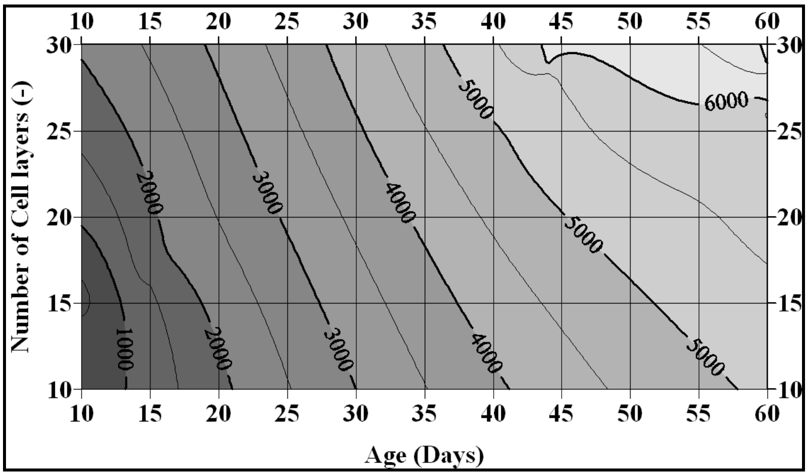


(b)

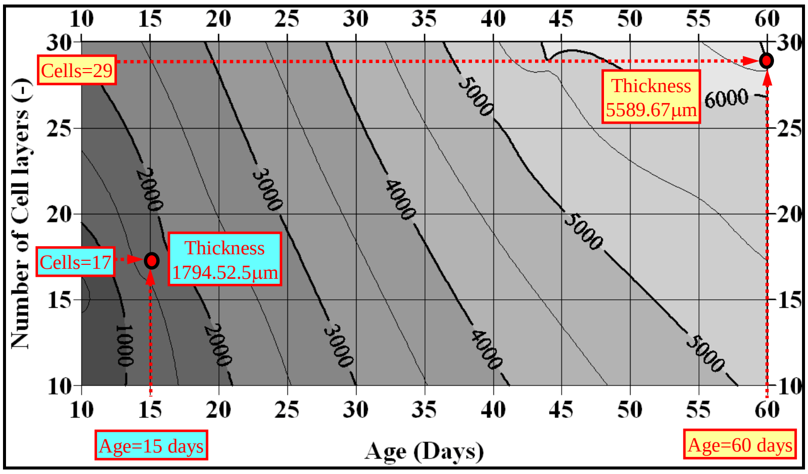
Fig. 5: (a) Dependency of exocarp thickness on the age and number of cells; (b) testing.

The topographic map that illustrates relationship between the thickness of tomato exocarp (µm) as dependent variable, against two independent variables, the tomato fruit age (daa) and number of cell layers within the pericarp (-), is presented in Fig. 5a. This topographic map illustrates that exocarp thickness varies in the similar manner as it is the case for pericarp – it also increases both with fruit aging (daa) and with increasing the number of cell layers (-) within the pericarp.

The map shown in Fig. 5a, has been also tested using acquired (measured) experimental data. Results of successful map testing are illustrated in the Fig. 5b.



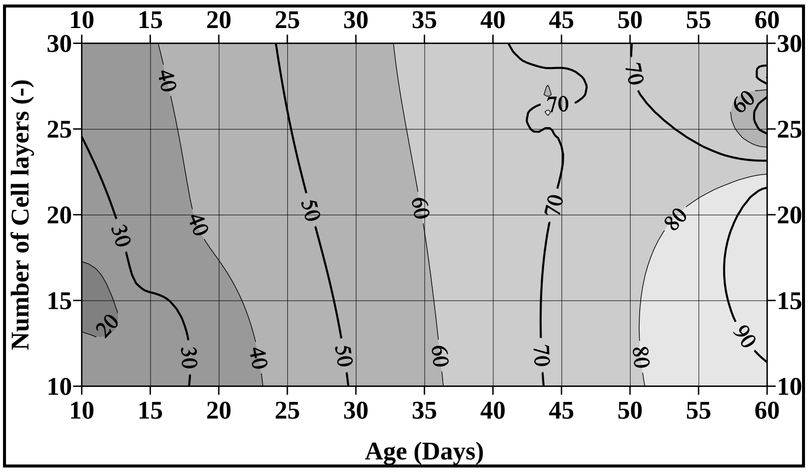
(a)



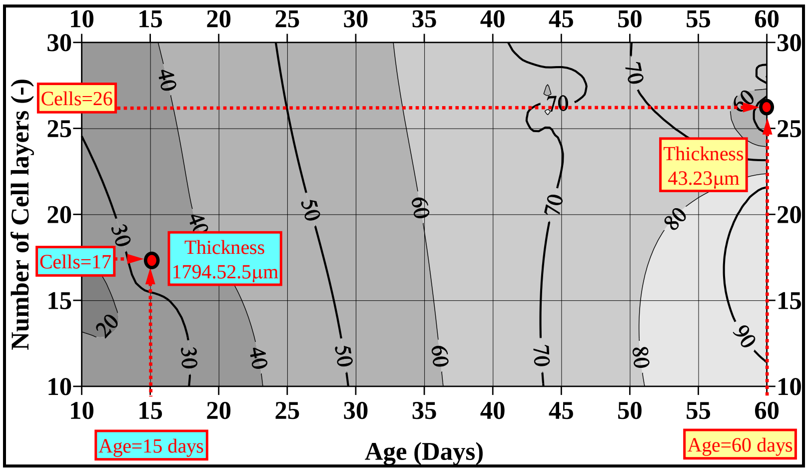
(b)

Fig. 6: (a) Dependency of mesocarp thickness on the age and cells number; (b) testing.

In the same manners, Figs. 6a and 7a present analogue relationships for the tomato mesocarp and endocarp thickness, respectively. These maps have been also successfully tested, as it is illustrated in Figs. 6b and 7b.



(a)



(b)

Fig. 7: (a) Dependency of endocarp thickness (µm) on the age (days) and cells number; (b) testing.

In general, tomato pericarp and it's cell layers (exocarp, mesocarp and endocarp) showed similar behavior during tomato growing process. As it was expected, layer thickness in all cases increased with tomato fruit aging and with increase of the cell number within a pericarp layer.

In the second stage of this study, interrelations between thicknesses of different tomato skin layers have been analysed. However, the strong linear interrelation was found only between thickness of mesocarp and pericarp. A results shown in Fig. 8 clearly indicate that thicknesses of these two skin layers were nearly identical.

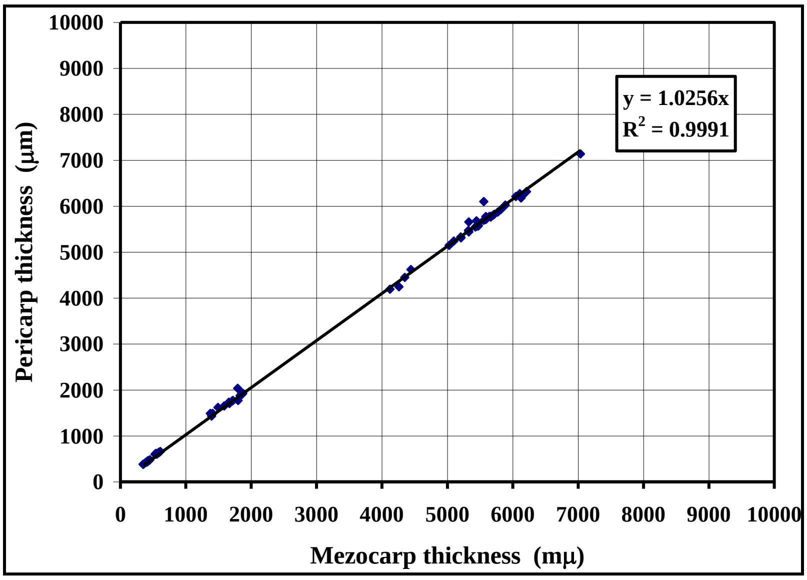


Fig. 8: Relationship between pericarp and mesocarp of tomato fruit skin.

Trend line, shown in this figure is y = 1.0256 x, where y is the thickness of pericarp, and x represents the thickness of mesocarp. In this case, the R-square factor is very high: 0.999. In other analysed cases, experimental "points" are still grouped, but the interrelations are not so clear. Therefore, additional detailed and comprehensive tests are needed in order to provide clear and reliable conclusions.

4. Conclusions

Pericarp is an important outer tissue complex of the tomato fruit. Consequently, the analysis of pericarp growth and development is crucial for prediction of fruit yield and quality. Detailed anatomical analysis of the pericarp of wild tomato, performed in this study, indicates positive fruit response to optimal irrigation treatment.

During the fruit development, clear linear relationship between the thickness of pericarp and mesocarp tissues has been evidenced. In contrast, exocarp and endocarp tissues had much slower growth and, comparing to mesocarp, practically had no influence on total pericarp size. Performed analysis enabled construction of topographical maps, which show relationships between the pericarp, exocarp, mesocarp and endocarp thickness toward the fruit age and number of cell layers. From the anatomical point of view, these kinds of maps enable more reliable control of tomato fruit production process.

Presented results indicate that the following research on development processes in tomato pericarp could be based on the effects of different irrigation treatments, e.g. deficit irrigation. This kind of approach will provide more reliable answers on the problems related to reactions of processes, which enable adequate fruit development and yield under water deficit.

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Expert paper

THE CHAOTIC AGRICULTURAL MONOPOLY OUTPUT GROWTH AND AN INDIRECT TAX

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Abstract. *The basic aim of this paper is to construct a relatively simple chaotic growth model of the agricultural monopoly output that is capable of generating stable equilibria, cycles, or chaos. An indirect tax is included in the model. A key hypothesis of this work is based on the idea that the coefficient* $\pi = \dfrac{f\,(1+d)}{2\,b\,(\alpha-1)}$ *plays a crucial role in explaining local stability of the agricultural monopoly output where: d – an indirect tax rate; f - the coefficient of the marginal cost function of the agricultural monopoly ; b- the coefficient of the inverse demand function,* α *- the coefficient of marginal revenue growth. The quadratic form of the marginal cost function of the agricultural monopoly is important ingredient of the model.*

Key words: *agricultural monopoly, output, indirect tax, chaos*

1. INTRODUCTION

Chaos theory can explain effectively unpredictable economic long time behavior arising in a deterministic dynamical system because of sensitivity to initial conditions. Chaos theory started with Lorenz's [10] discovery of complex dynamics arising from three nonlinear differential equations leading to turbulence in the weather system. Li and Yorke [9] discovered that the simple logistic curve can exibit very complex behaviour. Further, May [12] described chaos in population biology. Chaos theory has been applied in economics by Benhabib and Day [1,2], Day [3,4], Grandmont [6], Goodwin [7], Medio [13], Lorenz [11], Jablanovic [7,8], among many others.

2. THE MODEL

In the model of the agricultural monopoly firm in the short run, take the inverse demand function:

$$P_t = a - b\,Q_t. \tag{1}$$

where P – agricultural monopoly price; Q – agricultural monopoly output; a, b – the coefficients of the inverse demand function.

It is supposed that an indirect tax , T, increases the price of an agricultural good so that consumers are actually paying the tax by paying more for the agricultural products, i.e.,

$$T_t = d\,P_t \tag{2}$$

where T- an indirect tax, d – an indirect tax rate, P- agricultural monopoly price.

In this case,

$$(1+d)\,P_t = a - b\,Q_t\,, \tag{3}$$

or

$$P_t = \frac{a}{(1+d)} - \frac{b}{(1+d)}Q_t\,. \tag{4}$$

In this case, total revenue , TR_t , is given by

$$TR_t = P_t\,Q_t = \frac{a}{(1+d)}Q_t - \frac{b}{(1+d)}Q_t^2 \tag{5}$$

Further, suppose the quadratic marginal-cost function for the agricultural monopoly firm is

$$MC_t = e + f\,Q_t + g\,Q_t^{\,2} \tag{6}$$

MC – marginal cost; Q – agricultural monopoly output; c, f, g – the coefficients of the quadratic marginal-cost function. Marginal revenue is

$$MR_t = \frac{a}{(1+d)} - \frac{2\,b}{(1+d)}Q_t \tag{7}$$

MR – marginal revenue; a, b – the coefficients of the inverse demand function.

An agricultural monopoly firm maximizes profit by producing the quantity at which marginal revenue equals marginal cost. Thus the profit-maximizing condition is that

$$MR_t = MC_t\,. \tag{8}$$

Further,

$$MR_{t+1} = MR_t + \Delta\,MR, \tag{9}$$

i.e.,

$$MR_{t+1} = MR_t + \alpha\,MR_{t+1} \tag{10}$$

i.e.,

$$(1-\alpha)\,MR_{t+1} = MR_t \tag{11}$$

where α - the coefficient of marginal revenue growth.

Thus, the chaotic model of the profit-maximizing agricultural monopoly firm is presented by the equations (6), (7), (8) and (11). Firstly, it is supposed that a = 0 and e =0. By substitution one derives:

$$Q_{t+1} = \frac{f\ (1+d)}{2\,b\,(\alpha-1)}\,Q_t - \frac{g\ \ (1+d)}{2\,b\,(1-\alpha)}Q_t^{\ 2} \qquad (12)$$

where d is an indirect tax rate.

Further, it is assumed that the agricultural monopoly output is restricted by its maximal value in its time series. This premise requires a modification of the growth law. Now, the agricultural monopoly output growth rate depends on the current size of the agricultural monopoly output, Q, relative to its maximal size in its time series Q^m. We introduce q as $q = Q/Q^m$. Thus p range between 0 and 1. Again we index q by t, i.e., write q_t to refer to the size at time steps t = 0,1,2,3,... Now, growth rate of the agricultural monopoly output is measured as

$$q_{t+1} = \frac{f\ (1+d)}{2\,b\,(\alpha-1)}\,q_t - \frac{g\ \ (1+d)}{2\,b\,(1-\alpha)}q_t^{\ 2} \qquad (13)$$

This model given by equation (13) is called the logistic model. For most choices of α, b, d, f and g there is no explicit solution for (13). Namely, knowing α, b, d, f and g and measuring q_0 would not suffice to predict q_t for any point in time, as was previously possible. This is at the heart of the presence of chaos in deterministic feedback processes. Lorenz (1963) discovered this effect - the lack of predictability in deterministic systems. Sensitive dependence on initial conditions is one of the central ingredients of what is called deterministic chaos.

This kind of difference equation (13) can lead to very interesting dynamic behavior, such as cycles that repeat themselves every two or more periods, and even chaos, in which there is no apparent regularity in the behavior of q_t . This difference equation (13) will posses a chaotic region. Two properties of the chaotic solution are important: firstly, given a starting point q_0 the solution is highly sensitive to variations of the parameters α, b, d, f, and g; secondly, given the parameters α, b, d, f, and e the solution is highly sensitive to variations of the initial point q_0 . In both cases the two solutions are for the first few periods rather close to each other, but later on they behave in a chaotic manner.

3. THE LOGISTIC EQUATION

The logistic map is often cited as an example of how complex, chaotic behaviour can arise from very simple non-linear dynamical equations. The logistic model was originally introduced as a demographic model by Pierre François Verhulst. It is possible to show that iteration process for the logistic equation

$$z_{t+1} = \pi\, z_t\,(1 - z_t), \qquad \pi \in [0,4], \qquad z_t \in [0,1] \qquad (14)$$

is equivalent to the iteration of growth model (13) when we use the following identification:

$$z_t = \frac{(\alpha-1)\,g}{(1-\alpha)\,f} q_t \quad \text{and} \quad \pi = \frac{f\,(1+d)}{2\,b\,(\alpha-1)} \tag{15}$$

Using (13), and (15) we obtain

$$z_{t+1} = \frac{(\alpha-1)\,g}{(1-\alpha)\,f} q_{t+1} = \frac{(\alpha-1)\,g}{(1-\alpha)\,f}\left[\frac{f(1+d)}{2\,b\,(\alpha-1)} q_t - \frac{g\,(1+d)}{2\,b\,(1-\alpha)} q_t^{\,2}\right] =$$

$$= \frac{(1+d)\,g}{2\,b\,(1-\alpha)} q_t - \frac{(\alpha-1)(1+d)g^2}{2\,b\,f\,(1-\alpha)^2} q_t^{\,2} =$$

On the other hand, using (13), (14), and (15) we obtain

$$z_{t+1} = \pi\, z_t\,(1 - z_t) = \left[\frac{f\,(1+d)}{2\,b\,(\alpha-1)}\right]\left[\frac{(\alpha-1)\,g}{f\,(1-\alpha)}\right] q_t \left\{1 - \left[\frac{(\alpha-1)\,g}{f\,(1-\alpha)}\right] q_t\right\} =$$

$$= \frac{(1+d)\,g}{2\,b\,(1-\alpha)} q_t - \frac{(\alpha-1)(1+d)g^2}{2\,b\,f\,(1-\alpha)^2} q_t^{\,2} =$$

Thus we have that iterating $q_{t+1} = \frac{f\,(1+d)}{2\,b\,(\alpha-1)} q_t - \frac{g\,(1+d)}{2\,b\,(1-\alpha)} q_t^{\,2}$ is really the same as iterating $z_{t+1} = \pi\, z_t\,(1 - z_t)$ using $z_t = \frac{(\alpha-1)\,g}{(1-\alpha)\,f} q_t$ and $\pi = \frac{f\,(1+d)}{2\,b\,(\alpha-1)}$.

It is important because the dynamic properties of the logistic equation (14) have been widely analyzed (Li and Yorke [9], May [12]).

It is obtained that:

(i) For parameter values $0 < \pi < 1$ all solutions will converge to $z = 0$;
(ii) For $1 < \pi < 3{,}57$ there exist fixed points the number of which depends on π;
(iii) For $1 < \pi < 2$ all solutions monotonically increase to $z = (\pi - 1) / \pi$;
(iv) For $2 < \pi < 3$ fluctuations will converge to $z = (\pi - 1) / \pi$;
(v) For $3 < \pi < 4$ all solutions will continuosly fluctuate;
(vi) For $3{,}57 < \pi < 4$ the solution become "chaotic" which means that there exist totally aperiodic solution or periodic solutions with a very large, complicated period. This means that the path of z_t fluctuates in an apparently random fashion over time, not settling down into any regular pattern whatsoever.

4. CONCLUSIONS

This paper suggests conclusion for the use of the simple chaotic output growth model of a profit – maximizing agricultural monopoly firm. Further, it is supposed that an indirect tax, T, which increases the price of an agricultural good so that consumers are actually paying the tax by paying more for the agricultural products, is included in the model. The model (13) has to rely on specified parameters α, b, d, f, and g, and initial value of the agricultural monopoly output, q_0. But even slight deviations from the values of parameters α, b, d, f and g, and initial value of the agricultural monopoly output, show the difficulty of predicting a long-term behavior of the agricultural monopoly output, q_0.

A key hypothesis of this work is based on the idea that the coefficient $\pi = \frac{f\,(1+d)}{2\,b\,(\alpha-1)}$ plays a crucial role in explaining local stability of the agricultural monopoly output where: d – an indirect tax rate; f - the coefficient of the marginal cost function of the agricultural monopoly; b - the coefficient of the inverse demand function, α - the coefficient of marginal revenue growth. The quadratic form of the marginal cost function of the agricultural monopoly is important ingredient of the presented chaotic agricultural monopoly output growth model (13).

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USING THE ERROR FUNCTION FOR EVALUATION OF THE MIXING TRAILERS FOOD DISTRIBUTION UNIFORMITY

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Abstract. *The operation of mixing trailers is a complex process, influenced by many stochastic disturbances. The paper presents a simple novel approach, based on the „error function", formulated for evaluation of mechanized food distribution quality in the livestock barns. Two concepts of mixing trailers were tested: trailers equipped with the horizontal mixing rotors and those having the vertical mixing rotors. The experimental results, processed by the algorithm based on the „error function" showed that the best uniformity of food distribution was achieved with trailers having the horizontal rotors. The least efficiency was evidenced for the trailer equipped with single vertical rotor. It is verified that the „error function" algorithm is very efficient for evaluation of food uniformity distribution in livestock barns. An additional graphical method is also presented and verified as a simple and easily readable graphical complement of "error function".*

Key words: *mixing trailer, food distribution, error function, stochastic disturbances*

1. INTRODUCTION

Preparation of quality meal on livestock farms is one of most important parts in breeding process if high quality is to be expected, since productivity of this part of agricultural production depends on the management systems adopted and increases with the level of improved feeding and management [1-6]. The influence of the production and feeding systems that farmers use, on overall farm productivity, has often been ignored. There has been inadequate research on locally available, non-conventional feed resources and improvement in their management [7]. Poor feeding management is specially reflected on the negative energy balance periparturient dairy cows, including those cows that were raised in small-holder farms, where the problem is likely to be caused by improper feed and feeding management [8-10].

The feed and water supply systems are specific for each species. They should be adjusted to the height of the animals so that they can satisfy the vital needs of food and water. Regarding working conditions, the means should also meet the requirements of the person who takes care of the herd, and, finally, they should meet the requirements of the economic situation of the farm [11]. Equipment may be quite different according to the breeding system - intensive systems are generally characterized by high investment expenses, while extensive systems demand generally lower costs of this kind [12].

Mixing-distribution trailers represent a complex technical solution that can put together meal preparation, mixing and its distribution in various farm structures and buildings. However, their operation is influenced by many stochastic disturbances, which have to be accounted for and controlled carefully in order to provide a proper function of these machines. In addition, the introduction of new and beneficial technical systems can have a huge strike on the farmer's budget, forcing him to have a high-input/low-output traditional production. To improve the efficiency of the dairy cattle production and overall animal husbandry, an adequate veterinary extension service is needed during animal raising, supported by technique supply, marketing supervision and management, finance credit (fund), and policy-making [12-14]. Two main tasks of mixing-distribution trailer are: homogenization of meal concerning its numerous components; and uniform food distribution. Non-uniformity of meal distribution should not exceed 10-15% [11]. However, in the free keeping systems this value can be higher, but not more than 20%.

Question of skilled operator is also of high importance [15]. After conducting the survey among 900 farmers, [16] showed that their experiences with the mixers were generally good. They are still facing problems with the electronic weighing devices and with the question what type of trailers to choose. Horizontal and fan mixers required more repairs than the vertical ones. Further more, survey showed that vertical mixers treat the feed in the gentlest way and achieve a good mixing quality. It has been also reported that vertical mixers are cheaper with respect to the horizontal and are able to quickly and evenly dissolve silage bales [17]. Some authors [18-20] reported that question on the long run maintenance costs of the vertical mixers is still open. It is believed [21], that the precision of all the mixing trailers can be considered as good.

However, publications focused to the influence of mixer design on the food distribution uniformity in livestock buildings are still fairly rare. There are some reports about the uniformity of fertilizer particle distribution and possibilities of its optimization and modeling [22] developing a mathematical model which can describe the release rate of the fertilizers. So far, the most commonly used approach in the practice, specified for evaluation of the feed distribution uniformity is based on application of statistical coefficient of variation [23,24]. It is very simple, but provides only basic information.

This was the main motive of present study to establish an adequate evaluation method and to analyze the uniformity of mechanized livestock food distribution performed by four tested mixing trailers of different design. The new evaluation method, based on the so called "error-function", is a simple combination of analytical and graphical approach. Each of them can be used either simultaneously or independently. This method is still simple, but provides more detailed and reliable output information with respect to common approach based on the mean value and coefficient of variation.

2. MATERIAL AND METHODS

Four different mixing-distribution trailers, based on two rotor concepts, were tested in present paper regarding the uniformity of food distribution. Characteristics of the trailers are given in Table 1. Trailers were tested in dairy cattle farms of the Agricultural Cooperation Belgrade (Serbia). Based on feeding technology and regime for dairy cattle, maize silage, concentrate in briquettes, alfalfa hay and beer pomace were used for the meal preparation. Meal, formed by mixing all these components, was given two times per a day in two combinations:

I - silage : hay : concentrate = 83:7:10;

II – silage : hay : concentrate : beer pomace = 80 : 6 : 9 : 5.

Trailers were tested in the open area and in the barns. Optimal capacity and uniformity of distribution were investigated. Average trailer speeds were 3.83 km/h, 2.01 km/h, 1.34 km/h and 1.25 km/h for trailer A, B, C and D, respectively.

Table 1: Technical characteristics of tested trailers

Technical parameter	Trailer			
	A*	**B**♣	**C**†	D♥
Length of trailer [mm]	6990	9520	5650	4830
Width of trailer [mm]	2260	1850	2060	1950
Height of trailer [mm]	2850	2670	2670	2840
Maximal trailer's height [mm]	5670	4850	2670	2840
Trailer mass [kg]	6300	6900	4100	4100
Capacity [m^3]	12	15	12	10
Rotor orientation	horizontal	horizontal	vertical	vertical
Number of rotors	2	2	2	1
Side elevator speed [m/s]	0.38	0.35	0.34	0.38
Note		with silage cutter	with silage cutter	

*A - "LUCLAR" – model "Taurus 12 MC Vorax";

♣B - "SEKO" – model "Sam 5";

†C - "TRIOLET" – model "Solomix 2" and

♥D - "PEECON" – model "Biga 10".

For each tested machine, distributed food quantity (mass) q_i [kg] was measured at adequate locations on the left (denoted as x_i [kg]) and right side (denoted as y_i [kg]) of the aggregate. Tests were performed in real conditions. Therefore, the number of measured „points", as well as the nominal food quantities, varied between each of four different experiments: both of these two experimental parameters were imposed in each specific case, by the specific barn design and live-stock production technology.

To provide adequate conditions for comparison of results originating from different experiments, which were characterized by different values of nominal food quantity q_{nom} [kg], the non-dimensional relative values of distributed food quantities were used:

$$\hat{x} = \frac{x_i}{x_{nom}} = \frac{q_i}{q_{nom}} \text{ [-]}, \quad (1)$$

$$\hat{y} = \frac{y_i}{y_{nom}} = \frac{q_i}{q_{nom}} \text{ [-]}, \quad (2)$$

for the left and right side of the mixing trailers (i.e. barns), respectively. Namely, the closer the value of normalized food quantity to 1 means the more accurate food distribution at specified location (denoted as feeding/measuring point "point" in this paper). To comprehend all measuring points, which number *n* is different for each specific experiment and, therefore, for each tested mixing trailer type, the simple novel criterion is formulated. It is designated as the "error function":

$$Errf = \sqrt{\sum_{i=1}^{n} \left[(\hat{x}_i - 1)^2 + (\hat{y}_i - 1)^2 \right]} \text{ [-]}, \quad (3)$$

This criterion enables quantifying of the food distribution accuracy: the lower value of the error function means the higher accuracy. The basic advantages of this criterion lie in its independency on the number of deposition "points" and the nominal value of the food distribution quantity. In addition, it is very simple and suitable for fast field calculations.

3. RESULTS AND DISCUSSION

Tables 2, 3, 4 and 5 present basic statistical parameters that describe food distributions achieved by four tested mixing trailers of different designs. All parameters are simultaneously presented for the left (column 3) and right side (column 4), as well as an average values of left and right side of the machine (column 5).

Table 2: Statistical evaluation parameters of food distribution for the trailer A.

Relative variable [-]	$z=x/x_{nominal}$	Right side	Left side	Average ½*[(3)+(4)]	Absolute Difference | (3) – (4) |
(1)	(2)	(3)	(4)	(5)	(6)
Minimum	z_{min} [-]	0.69	0.94	0.82	0.25
Maximum	z_{max} [-]	1.38	1.33	1.35	0.05
Amplitude interval	Ap_z [-]	0.69	0.39	0.54	0.30
Arithmetic mean	m_z [-]	1.11	1.09	1.10	0.03
Mediane	Me_z [-]	1.18	1.07	1.13	0.11
The first quartile	Q_{1z} [-]	0.94	0.97	0.95	0.03
The third quartile	Q_{3z} [-]	1.26	1.18	1.22	0.08
Interquartile interval	Iqv_z [-]	0.32	0.21	0.27	0.11
Standard deviation	s_z [-]	0.22	0.13	0.17	0.09
Variation coeff.	C_{Vz} [%]	19.49	11.53	15.51	7.96
Amplitude coeff.	C_{Az} [%]	66.67	34.06	50.36	32.61
Interquartile coeff.	C_{IQVx} [%]	29.21	19.86	24.54	9.35
Skewness factor	S_z [-]	-0.76	0.69	-0.04	1.44
Flatness factor	F_z [-]	2.50	2.41	2.45	0.09

The absolute differences between the corresponding values of these parameters that characterize the left and right side are given in the column (6). In addition, normalized food quantity distributions are graphically illustrated in the Figs. 1a-d, for each of these four trailers.

Table 3: Statistical evaluation parameters of food distribution for the trailer B.

Relative variable [-]	$z=x/x_{nominal}$	Right side	Left side	Average ½*[(3)+(4)]	Absolute Difference | (3) – (4) |
(1)	(2)	(3)	(4)	(5)	(6)
Minimum	z_{min} [-]	0.94	0.90	0.92	0.03
Maximum	z_{max} [-]	1.18	1.09	1.14	0.09
Amplitude interval	Ap_z [-]	0.25	0.19	0.22	0.05
Arithmetic mean	m_z [-]	1.06	1.01	1.04	0.05
Mediane	Me_z [-]	1.05	1.05	1.05	0.00
The first quartile	Q_{1z} [-]	1.00	0.93	0.97	0.07
The third quartile	Q_{3z} [-]	1.17	1.09	1.13	0.09
Interquartile interval	Iqv_z [-]	0.17	0.15	0.16	0.02
Standard deviation	s_z [-]	0.08	0.07	0.07	0.01
Variation coeff.	C_{Vz} [%]	7.57	6.77	7.17	0.80
Amplitude coeff.	C_{Az} [%]	23.35	19.29	21.32	4.06
Interquartile coeff.	C_{IQVx} [%]	15.48	15.15	15.32	0.33
Skewness factor	S_z [-]	0.00	-0.58	-0.29	0.58
Flatness factor	F_z [-]	2.03	1.77	1.90	0.27

Table 4: Statistical evaluation parameters of food distribution for the trailer C.

Relative variable [-]	$z=x/x_{nominal}$	Right side	Left side	Average ½*[(3)+(4)]	Absolute Difference | (3) – (4) |
(1)	(2)	(3)	(4)	(5)	(6)
Minimum	z_{min} [-]	0.31	0.95	0.63	0.63
Maximum	z_{max} [-]	1.18	1.57	1.38	0.39
Amplitude interval	Ap_z [-]	0.87	0.63	0.75	0.24
Arithmetic mean	m_z [-]	0.87	1.25	1.06	0.38
Mediane	Me_z [-]	0.94	1.19	1.06	0.25
The first quartile	Q_{1z} [-]	0.76	1.04	0.90	0.28
The third quartile	Q_{3z} [-]	1.01	1.53	1.27	0.52
Interquartile interval	Iqv_z [-]	0.25	0.48	0.37	0.23
Variation coeff.	C_{Vz} [%]	21,20	20,85	21,02	0,35
Standard deviation	s_z [-]	0.24	0.24	0.24	0.00
Amplitude coeff.	C_{Az} [%]	116.20	49.80	83.00	66.40
Interquartile coeff.	C_{IQVx} [%]	28.31	37.67	32.99	9.36
Skewness factor	S_z [-]	-1.22	0.18	-0.52	1.40
Flatness factor	F_z [-]	3.79	1.36	2.57	2.43

Table 5: Statistical evaluation parameters of food distribution for the trailer D.

Relative variable [-]	$z=x/x_{nominal}$	Right side	Left side	Average ½*[(3)+(4)]	Absolute Difference | (3) – (4) |
(1)	(2)	(3)	(4)	(5)	(6)
Minimum	x_{min} [-]	0,73	0,74	0,73	0,01
Maximum	x_{max} [-]	1,28	1,36	1,32	0,08
Amplitude interval	Ap [-]	0,55	0,62	0,58	0,07
Arithmetic mean	m_x [-]	0,97	1,01	0,99	0,04
Mediane	Me_x [-]	0,94	0,94	0,94	0,00
The first quartile	Q_{1x} [-]	0,78	0,80	0,79	0,03
The third quartile	Q_{3x} [-]	1,19	1,24	1,21	0,05
Interquartile interval	Iqv_x [-]	0,41	0,43	0,42	0,02
Standard deviation	s_x [-]	0,21	0,21	0,21	0,00
Variation coeff.	C_{Vx} [%]	21,20	20,85	21,02	0,35
Amplitude coeff.	C_{Ax} [%]	54,55	59,01	56,78	4,46
Interquartile coeff.	C_{IQVx} [%]	42,03	42,52	42,28	0,49
Skewness factor	S_x [-]	0,15	0,31	0,23	0,16
Flatness factor	F_x [-]	1,30	1,62	1,46	0,32

Although both the tables and the figures provide useful information, they are inappropriate for the practical purposes: a lot of information is available, but it is not easy to extract crucial data and make adequate decision on the base of these data. Therefore, a single criterion, the so-called "error function" (3) has been formulated and applied in this paper as the main criterion for evaluation of the food distribution uniformity and accuracy.

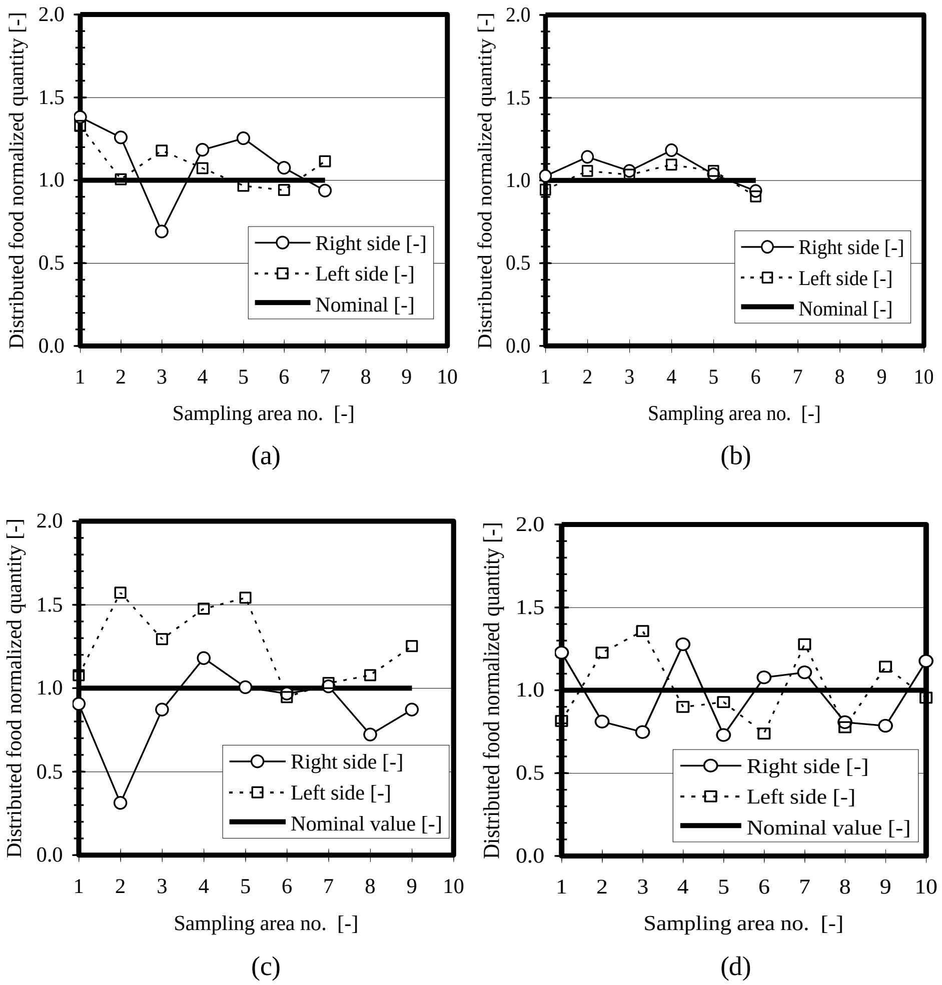

Fig. 1. Relative (normalized) food distributions of different mixing trailers: (a) Trailer A; (b) Trailer B; (c) Trailer C and (d) Trailer D.

The error function reaches the lowest value (0.1243) for the horizontal mixer type B with two rotors, while the highest value is 0.4413 for the vertical mixer trailer type C possessing two rotors. These values verify that horizontal mixer with two rotors achieved the most uniform food distributions under specified testing conditions, while the lowest accuracy was achieved when the vertical trailer with two rotors was used. The moderate accuracy of food distribution was in the case of horizontal trailer with two rotors (type A) and in case of vertical mixer with one rotor (type D), which error functions took the similar values: 0.2869 and 0.2964, respectively.

The introduction of error-function is graphically supplemented, as it is presented in Figs. 2a-d. These figures show the highest concentration of the experimental points around the point (1, 1), which correspond to perfect accuracy of food distribution, when the two rotor horizontal mixer of type B was used. The largest dispersion of experimental points around the ideal point (1, 1) was in the case of vertical mixer with two rotors, type C. This way, a graphical counterpart of the error-function criterion can be used for the same purpose. This method is highly descriptive, and represents a useful supplement to the approach based on application of the error function.

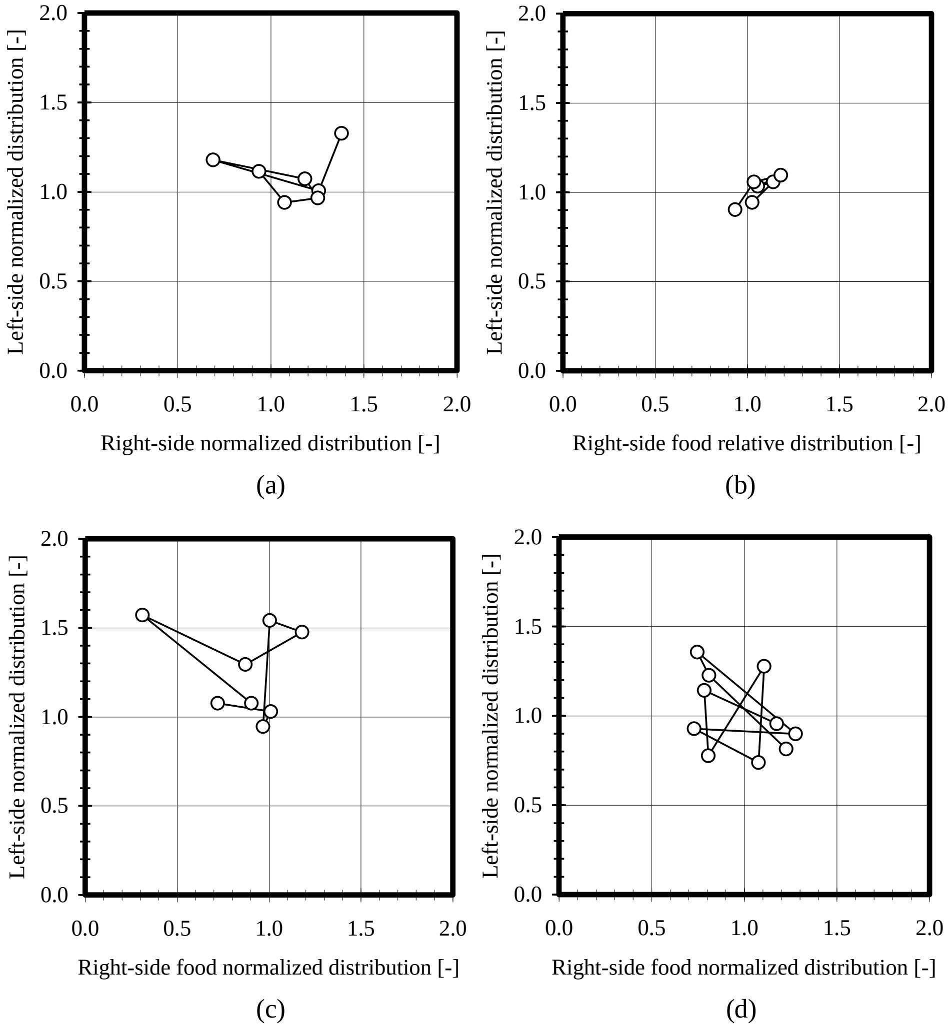

Fig. 2. Normalized food distribution of different mixing trailers – normalized quantities on the left-side v.s. analogue values on right-side of the machine: (a) Trailer A, (b) Trailer B; (c) Trailer C and (d) Trailer D.

In contrast to descriptive statistical parameters, this approach is much simpler and more concise: the error function approach is based on single criteria - it utilizes a single number value. Therefore, it is practical and reliable, and provides high accuracy as well.

An important advantage of such approach lies in its independency on the experimentalists experience and sensitivity.

4. CONSLUSIONS

Regardless the automatization, trends in the cattle husbandry, mixing and efficient food distribution are of great importance. Shared use of the mixing-distribution trailers can still enable medium-sized farms to keep mechanization cost low as well as to decrease the energy consumption. If the food distribution is adequate and uniform, the energy and economy benefits can be expected consequently.

This paper describes a possible way for evaluation of mixing trailers working quality. Presented approach is based on error function. The new simple criteria - “error function”, enables quantifying of the food distribution accuracy and uniformity. Obtained results also show that the best quality of food distribution can be expected with the use of horizontal mixing-distribution trailers with two rotors. This can also be read from the simple graphical representation of the values. The application of the error function and graphical method evaluation for a food distribution system quality will be easier and more reliable in comparison to existing methods.

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Scientific review paper

THE IMPACT OF LAND USE ON SOIL EROSION AND RUNOFF IN THE KRIVAJA RIVER BASIN IN MONTENEGRO

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Abstract. *Modelling of soil erosion should be one of priorities for soil conservation because of better understanding of the soil erosion phenomenon, what is further important for preventing the land degradation. For the Krivaja River Basin of Polimlje the authors studied soil erosion processes, using a series of data that are characterizing variations in land use over the period of four decades. The computer-graphic modelling was used to calculate soil erosion intensity analysing data of Forest Management Plans, Cadastre, Landsat images and Statistical Yearbooks. It was concluded that the condition of the vegetation cover and the land use have influenced the development of erosion processes in the territory of the subject river basin. The authors calculated the maximal outflow from the river basin on 42* m^3s^{-1}*. Research shown that the river basin belongs in „Destruction Category IV", according to the classification system of Gavrilovic. The strength of the erosion process is weak. The real soil losses from the river basin are over 1200 m³/year. The results indicated that decrease of grassland did not pose a significant risk to soil erosion, because of continual increase of areas under the forests. Change of the land use in structure for the period of four decades (1970-2013), in the studied river basin, decreased the soil erosion intensity for 3.43%.*

Key words: *soil erosion, runoff, land use, modelling, prediction, IntErO model*

1. INTRODUCTION

Soil erosion is one of the greatest environmental problems in the South Eastern Europe, but unfortunately not the main concern for their state officials and policy makers dealing with land degradation, since there are no visible actions to combat this problem in the Region. The interventions are in general reduced to solving the problems partially at the local level. Once the consequences become evident, the action taken are much more costly and in some cases is too late to discontinue the process of the land degradation.

Land degradation caused by soil erosion is especially serious in Montenegro. Its reduction to preserve soil quality and to maintain land productivity constitutes a major challenge for soils in mountainous areas [4]. According to Spalevic [30], Kostadinov *et al.* [18], Kadovic [17] and Lazarevic [19], water erosion has affected 13,135 km^2 or 95% of the total territory of Montenegro (13,812 km^2). The remaining area is characterised by alluvial accumulation. Erosion caused by water is dominant in terrain with steep slopes due to complex physical and geographical conditions paired with reckless logging [28].

This is the reason of suggesting the modelling soil erosion and runoff for this Region, establishing the early warning as an action of prevention.

Contrary to the states administration of the region, the science and researchers are more sensible to the soil erosion as the most widely recognized and most common form of land degradation and a major cause of falling productivity [38]. Quantitative information on soil loss is needed for erosion risk assessment [30] and to establish the effectiveness of improved land management practices [27]. The approaches of the various researchers to "measure the values" are different. The uses of various indicators that are related to soil erosion are different. Most of these indicators focus, however, on small spatial units, while little attention has been given to the amount of sediment exported at the catchment scale. Small spatial unit approach neglects the transfer of sediment through catchments as well as the scale-dependency of erosion processes. Furthermore, small spatial unit approach does not consider important off-site impacts of soil erosion, such as sediment deposition in reservoirs, flooding as well as ecological impacts [39].

This was the reason why the authors of this study approach this problem on catchment scale.

This approach requires the collection of field data, various measurements, as well as processing of those data through the predictive models for the evaluation of different management scenarios for the soil conservation. Field measurements of erosion and sedimentation using classical techniques is time-consuming and expensive [4]. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both the runoff and soil loss [40].

This was the reason why the authors of this study analyse this problem using computer-graphic methods, illustrating the possibility of modelling of sediment yield and runoff with such approach.

2. MATERIAL AND METHOD

The research was carried out in the period of 1999-2011 as a part of the research on Soil erosion processes in the Polimlje region, North of Montenegro [30], funded by the Ministry of Science of Montenegro.

The river Lim is the most important Montenegrin watercourse from a hydrographic perspective. The River Basin is called Polimlje (coordinates: 43.2457 N, 19.5803 E (North); 42.5080 N, 19.9058 E (South); 43.1480 N, 19.4856 E (West); 42.9639 N, 20.1200 E (East). It consists of 57 watersheds, of which ten are located in the Berane valley: 1) Navotinski Potok, 2) Vinicka, 3) Rovacki, 4) Krivaja, 5) Bistrica, 6)

Kaludarska, 7) Makva, 8) Susica, 9) Dapsicka and 10) Crepulja (Lucka). This research focuses on the Krivaja Basin (Fig. 1).

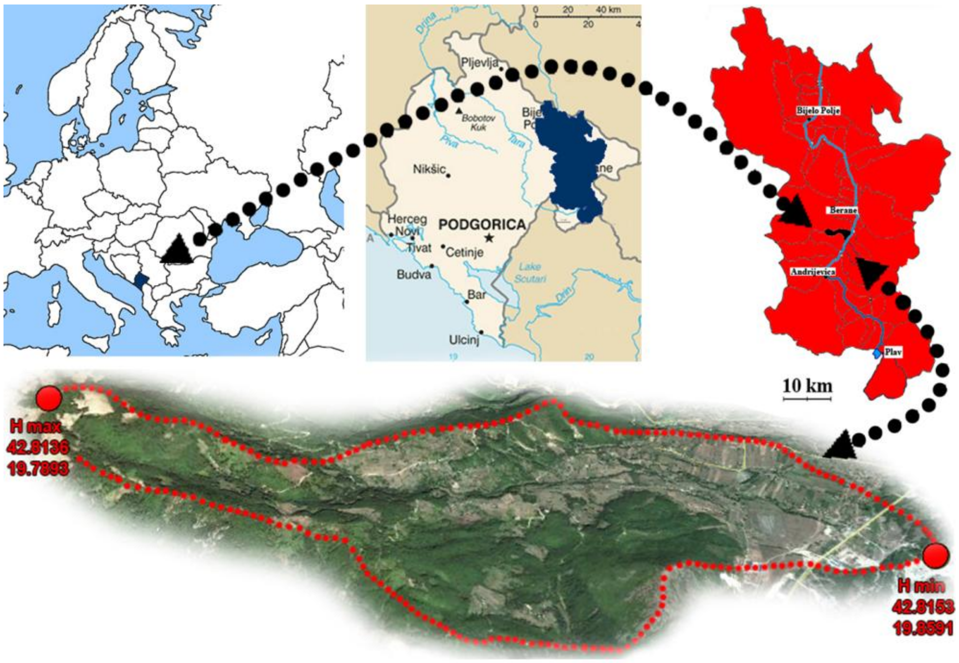


Fig. 1: Study area of Krivaja river basin.

Krivaja is a left-hand tributary of the River Lim and is placed between the two big river basins: Bistrica on the North, and Vinicka river basin on the South. The watershed is going on the south from Meka (1650m absl), over Kule and Gradina, and on the north over the village Buce.

The Krivaja River Basin encompasses an area of 9.1 km. Fieldwork was undertaken to collect detailed information on the forms of soil erosion, the status of the vegetation cover, the type of land use. Morphometric methods were used to determine the slope, specific lengths, expression and form of the slopes, the density of the erosion rills, the degree of the rills and other relevant parameters.

We drew on the earlier pedological work of Fustic and Djuretic, who analysed the physical and chemical properties of all Montenegrin soils [16] from 1964 to 1988, including those in the study area of the Krivaja River Basin. Furthermore, some pedological profiles had been reopened in the last five years, and soil samples were taken for physical and chemical analyses.

The granulometric composition of the soil was determined using the pipette method; the samples were prepared using sodium pyrophosphate. The soil reaction (pH in H_2O and nKCl) was determined with a potentiometer. The total carbonates were determined by the volumetric Scheibler method; the content of the total humus was determined by the Kotzman method; easily accessible phosphorous and potassium were determined by the Al-method; and the adsorptive complex (y1, S, T, V) was determined by the Kappen method.

Estimating soil erosion and sediment yield requires comprehensive recognition of various factors, but identification of the parameters is difficult because of the complexity of soil erosion phenomena [12]. There are a number of relevant empirical evaluation methods. These methods involve several steps: data acquisition, model specification and estimation [13].

Based on previous experience, the most reliable method for determining sediment yields and intensity of erosion processes for the subject area is the Erosion Potential Method [13], which is distinguished by its high degree of reliability in calculating sediment yields as well as transport and reservoir sedimentation [24]. It is the most suitable on catchment level for the watershed management needs in this Region [3].

Sediment yields were calculated with the Erosion Potential Method (EPM) on 347,273 m^3/year for the 57 basins of Polimlje in Montenegro [30]. The calculations correspond to the measured values obtained at the Potpec accumulation which is downstream from the study area. This correspondence suggests that results of the assessment of actual losses of soil erosion potential obtained by EPM are applicable to the study area [28, 29, 30]. The impact of land use on soil erosion and runoff in the subject area we analyse using computer-graphic methods. The authors in selection of the model were aware that several software have been developed to predict the soil erosion from agricultural runoff, such as GWLF [25] SMDR [14] and SWAT [11]. Application of the Water Erosion Prediction Project (WEPP) [21] was considered also as it is a frequently used to simulate the water erosion and sediments [20] as well as Artificial Neural Networks (ANNs) as an alternative modelling method [1]. Finally, taking into consideration earlier verifications of the models in the studied area it was decided to evaluate the interaction of land use with soil erosion characteristics in the Krivaja River Basin of Polimlje, using the Intensity of Erosion and Outflow (IntErO) model [30]. Erosion Potential Method is embedded in the algorithm of this computer-graphic method.

3. Results and discussion

3.1. Physical-geographical characteristics and erosion factors

The area of the Krivaja River Basin is located from its inflow to the river Lim (Hmin, is 691 m) up to the watershed boundary with Bistrica and Vinicka Rijeka, where the Hmax is 1650 m (Meka). The natural length of the main watercourse, Lv, is 7.4 km. The shortest distance between the source and the mouth, Lm, is 6.99 km. The total length of the main watercourse, with tributaries of I and II class, ΣL, is 8.44 km. The average river basin decline, Isr, is 24.29%; the average river basin altitude, Hsr, is 929.77 m; the average elevation difference of the river basin, D, is 238.77m.

In the area close to the inflow of the Krivaja River to the River Lim, there are moderate slopes around the village Buce. The upper part of the basin is characterised by a narrow valley that is 2.8 km long (ground length), with an average width of about 600 m. It is characterised by the steep slopes compared with the lower parts of the basin. Regardless, erosion processes are not very intense in this part of the basin as there is a good cover of forest vegetation.

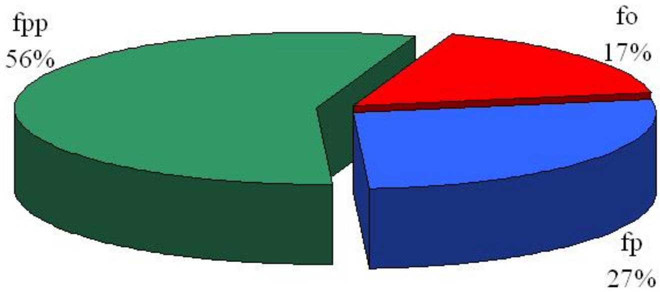
3.2. Climatic characteristics (hb, t_0 and Hgod)

Climate in the Krivaja River Basin is characterised by short and dry summers; rainy autumns and springs; and cold winters. The absolute maximum air temperature is 37.8^{O}C. Winters are severe with temperatures falling to a minimum of -28.3^{O}C. The volume of torrential rain, hb, is 71.9 mm. The average annual air temperature, t_0, is 9°C. The average annual precipitation, Hgod, is 944 mm.

3.3. The geological structure of the area

In the structural-tectonic sense, the area belongs to the Durmitor geotectonic unit of the Inner Dinarides of northern and north-eastern Montenegro [41]. The geological structure of the area consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous-Paleogene and Neogene sediments and Quaternary.

The coefficient of permeability for the region's bedrock, S1, is 0.67. The structure of the Krivaja River Basin, according to bedrock permeability, is presented in Fig. 2.



A part of the river basin consisted of a very permeable rocks, fp;
A part of the river basin area consisted of medium permeable rocks, fpp
A part of the river basin area consisted of not permeable rocks, fo

Fig. 2: Structure of the Krivaja River Basin
according to the permeable products from rocks.

3.3. Soil characteristics of the area

Soil properties always have an effect on the intensity of erosion, a fact that has been generally accepted and confirmed by various authors. Those studies paid particular attention to the types of soil and their properties, with particular focus on their propensity towards erosion [28, 29].

The most common soil types in the studied river basin are: brown district (acid) soils, (on sandstone, granite, and gneiss), 5.31 km^2; brown eutric soils, 1.68 km^2; limestone and dolomite soils, 1.18 km^2; and alluvial-deluvial soils, 0.92 km^2. Some smaller surfaces in the river basin, insignificant for the calculation of soil erosion intensity, are rankers and rendzina soils.

The structure of the Krivaja River Basin, according to the soil types, is presented in Fig. 3 and one of the soil profiles on Fig. 4.

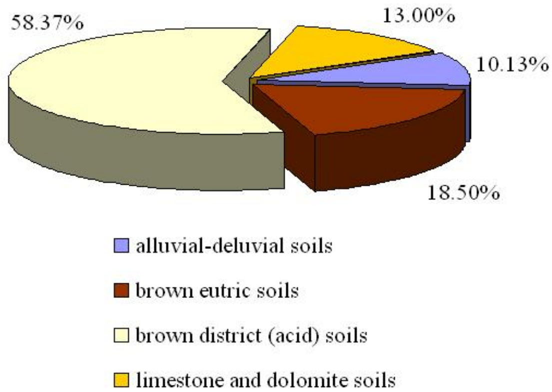


Fig. 3: The structure of the Krivaja River Basin, according to the soil types.

Fig. 4: One of the Soil profiles.

3.4. Land use and characteristics of the basin regarding issues of soil erosion

The control of soil erosion processes depends on appropriate land use and management planning [10]. One of the most important aspects of vegetation in relation to water resource management is its capability to reduce erosion. Through soil stabilisation, adequate vegetation cover minimises erosion and reduces water quality impairment caused by sedimentation.

Water-induced soil erosion is the result of the complex effects of a large group of factors. In their research, Lazarevic [19], Curovic *et al.* [8], Spalevic [36], Spalevic *et al.* [34], Fustic and Spalevic [15], Spalevic *et al.* [33] and Spalevic [30] showed that erosion intensity is always influenced by soil properties and land use, the latter becoming increasingly important since the beginning of the anthropogenic period of the land's evolution. Over the last forty years, anthropogenic factors have significantly increased the pressure on agricultural land, degrading vegetation cover and eventually resulting in serious degradation and loss of fertile soil [28, 29].

The subject area belongs to the Dinaridi Province of the Middle-Southeast European mountainous biogeographical region. The dominant vegetation consists of forests, which account for more than two thirds of the total vegetation cover.

Plant communities of the subject area belong to the following vegetation classes: *Querco-fagetea*; *Quercetea robori-petreae*; *Betulo-adenostiletea*; *Epilobietea angustifolii*; *Salicetalia purpureae*; *Alnetea glutinosae*; *Arhenanteretea*; *Festuco brometea*; *Plantaginetea majoris*; *Secalinetea*; *Caricetea curvulae*; *Elyno-seslerietea*; *Salicetea herbacea*.

On the vertical profile, the subject basin includes the following forest communities:

- *Quercetum petraeae-cerridis*, Lak. Mostly on southern exposures of valleys along the main watercourse, and the lower parts of its tributaries.
- *Quercetum petraeae montenegrinum*, Lak. On hilly portions of the river basin.
- *Fagetum montanum.* Differentiated into several associations of which the most characteristic is Luzulo - *Fagion moesiacae.*
- *Fagetum subalpinum*, above 1500 m including all exposures and various geological substrates.

Most of the river basin is covered by low beech forests *(Fagetum montanum).* Beech forests are characterized by dense canopy. Beech as a species tolerates shade well, particularly in youth, its growth and increment depend very much on the quantity of light. Absence of light can slow down beech growth significantly [7]. On the southern exposures there are forests of Sessile oak and Turkish oak *(Quercetum petraeae-cerridis).* A narrow belt near the river in the lower part of the river basin is covered with hygrophilic forest *(Alnetea glutinosae, Salicetea herbacea).* At the highest altitudes of the basin there are subalpine forests of beech [31].

In last decades climate change on forest ecosystems affected moving of the vegetation vertical layout belts [6].

According to our analysis in 2013, the coefficient $f_{s,}$ (portion of the river basin under forest cover), is 0.65; f_t (grass, meadows, pastures and orchards) is 0.31 and f_g (bare land, ploughed land and ground without grass vegetation) is 0.04.

The coefficient of the river basin planning, X_a, is 0.44. Of the total river basin area, related to the river basin structure, degraded forests are the most widespread form (39.24%). The proportion is as follows: well-constituted forests (26.16%), meadows (16.32%), mountain pastures (10.04%), orchards (4.2%), and ploughed lands (3.68%). The coefficient of the vegetation cover, S_2, is 0.68. A summary of land use in the Krivaja River Basin is presented in Fig. 5.

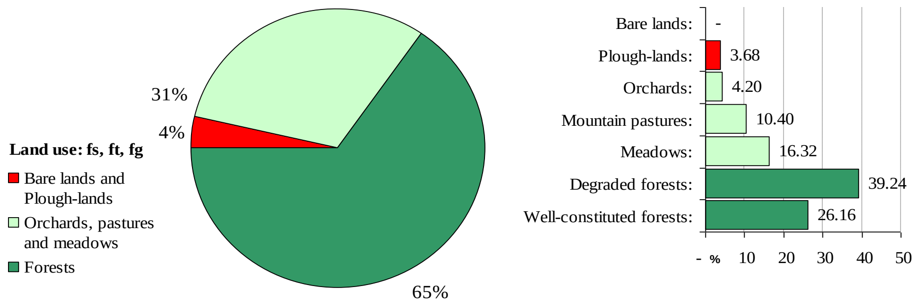


Fig. 5: Land use in the Krivaja River Basin (in 2013).

Using a series of data of Forest Management Plans, Cadastre, Landsat images and Statistical Yearbooks that are characterizing variations in land use over the period of four decades (1970-2013) it is concluded that:

- Area under forests is prevailing; meadows, pastures and orchards covers around 30% of the studied area; ploughed land and ground without grass vegetation are equal or less than 5.5% of the studied river basin (Fig. 6);
- Increase of areas under the forests over the period of time are presented in Fig. 7;
- Decrease of areas under the grassland is presented in Fig. 8; the areas under bare lands & plough-lands on Fig. 9.

Terrain relief of the basin is characterised by a high percentage of steep slopes in the central and upper part of the basin from which water rapidly runs off. This situation is favourable for triggering soil erosion. Sheet erosion dominates in this area.

Erosion affects some areas of agricultural and forest land above the village Buce, but it mostly occurs close to the rural roads in the upper part of the river basin. Erosion processes causes some site to lose fertile soils, and results in sterile alluvial deposits over the alluvial terraces close to the main watercourse downstream (Figs. 10, 11, 12). It has also resulted in torrents, which have flooded roads and interrupted travel in the lower part of the basin.

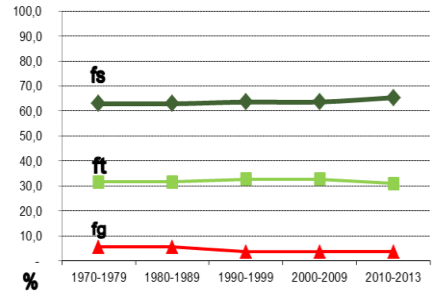


Fig. 6: Land use (period 1970-2013).

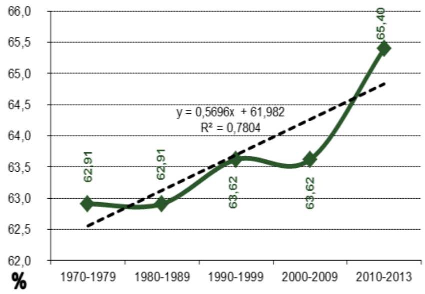


Fig. 7: Forests (fs).

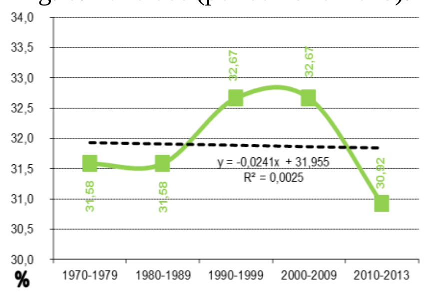


Fig. 8: Orchards and meadows (ft).

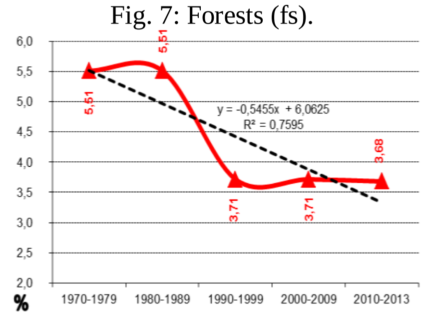


Fig. 9: Bare lands, & Plough-lands (fg).

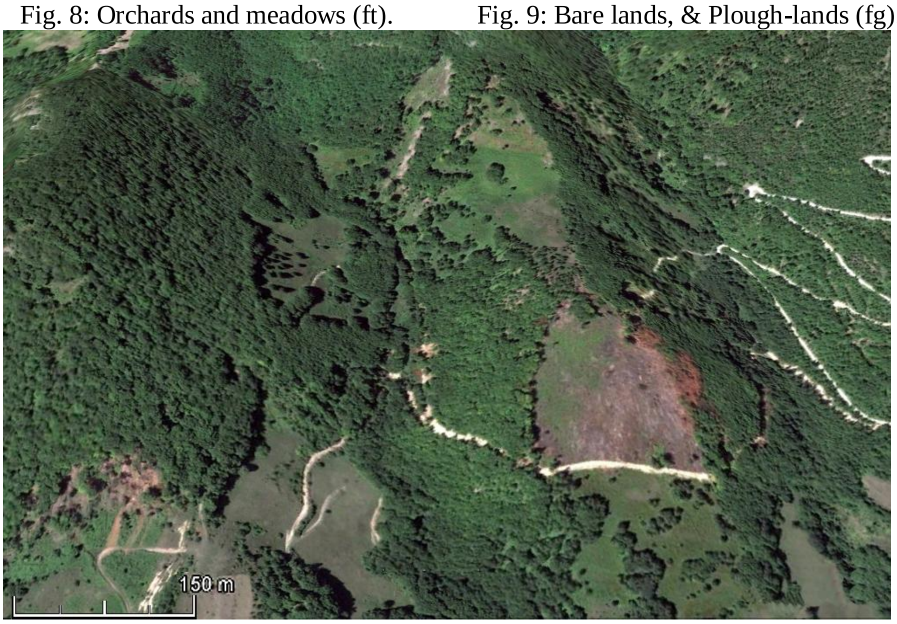


Fig. 10: Detail from the upper part of the River Basin (Google earth).

Fig. 11: The rural road in the river basin damaged by water induced erosion.

Fig. 12: Alluvial terraces at the lower part of the river basin - Gradinsko polje.

We used IntErO software [30] to process the input data required for calculation of the soil erosion intensity and the maximum outflow processing a series of data that are characterizing variations in land use over the period of four decades. The results indicated that decrease of grassland did not pose a significant risk to soil erosion, because of continual increase of areas under the forests. Support of faster vegetation recovery with some biological protection measures need to be applied. These would prevent rapid runoff and maintain low transport of erosion material.

The IntErO report for the studied basin is presented in Table 1.

Table 1a: Part of the IntErO report for the Krivaja River Basin - inputs.

	Year:	1970	1990	2013	
Inputs					
River basin area	F		9,06		km²
The length of the watershed	O		18,84		km
Natural length of the main watercourse	Lv		7,39		km
The shortest distance between the fountainhead and mouth	Lm		6,99		km
The total length of the main watercourse with tributaries of I and II class	ΣL		8,44		km
River basin length measured by a series of parallel lines	Lb		6,31		km
The area of the bigger river basin part	Fv		6,52		km²
The area of the smaller river basin part	Fm		2,54		km²
Altitude of the first contour line	h0		700		m
Equidistance	Δh		100		m
The lowest river basin elevation	Hmin		691		m
The highest river basin elevation	Hmax		1650		m
A part of the river basin consisted of a very permeable products from rocks	fp		0,27		
A part of the river basin area consisted of medium permeable rocks	fpp		0,56		
A part of the river basin consisted of poor water permeability rocks	fo		0,17		
A part of the river basin under forests	fš	**0,63**	**0,64**	**0,65**	
A part of the river basin under grass, meadows, pastures and orchards	ft	**0,32**	**0,33**	**0,31**	
A part of the river basin under bare land, plough-land and ground without grass vegetation	fg	**0,06**	**0,04**	**0,04**	
The volume of the torrent rain	hb		71,9		mm
Incidence	Up		100		years
Average annual air temperature	t0		9		°C
Average annual precipitation	Hgod		944,3		mm
Types of soil products and related types	Y		1		
River basin planning, coefficient of the river basin planning	Xa	**0,45**	**0,44**	**0,44**	
Numeral equivalents of visible and clearly exposed erosion process	φ		0,26		

Table 1b: Part of the IntErO report for the Krivaja River Basin - results.

	Year:	1970	1990	2013	
Results					
Coefficient of the river basin form	A	0,5			
Coefficient of the watershed development	m	0,69			
Average river basin width	B	1,44			km
(A)symmetry of the river basin	a	0,88			
Density of the river network of the basin	G	0,93			
Coefficient of the river basin tortuousness	K	1,06			
Average river basin altitude	Hsr	929,88			m
Average elevation difference of the river basin	D	238,88			m
Average river basin decline	Isr	25,03			%
The height of the local erosion base of the river basin	Hleb	959			m
Coefficient of the erosion energy of the river basin's relief	Er	175,93			
Coefficient of the region's permeability	S1	0,67			
Analytical presentation of the water retention in inflow	W	0,9061			m
Energetic potential of water flow during torrent rains	2gDF^½	206,11			m km s
Temperature coefficient of the region	T	1			
Coefficient of the vegetation cover	**S2**	**0,69**	**0,68**	**0,68**	
Maximal outflow from the river basin	**Qmax**	**42,75**	**42,42**	**42,21**	**m³/s**
Coefficient of the river basin erosion	**Z**	**0,331**	**0,325**	**0,323**	
Production of erosion material in the river basin	**Wgod**	**5117,4**	**4982,5**	**4942,1**	**m³/god**
Coefficient of the deposit retention	Ru	0,244			
Real soil losses	**Ggod**	**1248,25**	**1215,35**	**1205,46**	**m³/god**
Real soil losses per km2	**Ggod/km²**	**137,71**	**134,08**	**132,99**	**m³/km² god**

The impact of land use on soil erosion intensity and runoff in the Krivaja river basin is may be better understood analysing the graphics presented on Figs. 13 – 16.

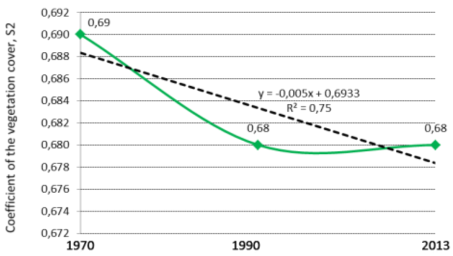


Fig. 13: Vegetation cover coefficient.

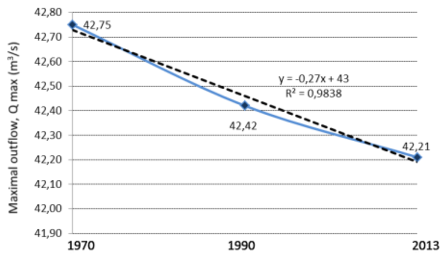


Fig. 14: Maximal outflow from the basin.

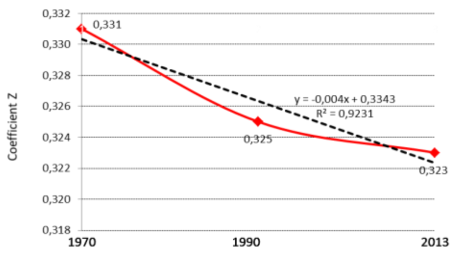


Fig. 15: River basin erosion coefficient.

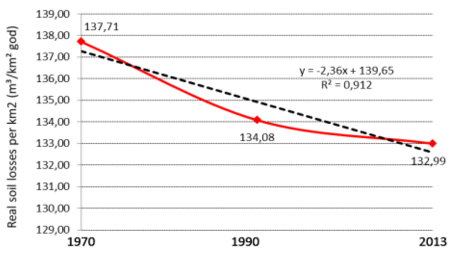


Fig. 16: Real soil losses per km^2.

Those graphics explained that the value of the Vegetation cover coefficient (S2) stabilised on 0.68 after the decade 1990. As a result, the predicted value of the maximal outflow from the basin (Fig. 15) is slightly decreased: from 42.75 m^3/s (decade 1970) to 42.21 m^3/s (the year 2013). The reduction in quantity is insignificant, but it is important that the trends of the maximal outflow from the river basin are not greater than before. The process of runoff, according to this indicator, is not in increase.

The values of the River basin erosion coefficient (Fig. 15) are also decreasing. Real soil losses for the river basin per year (Fig. 16) are decreased for 42.79 m^3/year, from 1248.25 m^3/year (for the decade 1970) to 1205.46 (for 2013).

Change of the land use in structure for the period of four decades (1970-2013), in the studied river basin, according to our analyses, decreased the soil erosion intensity for 3.43%.

Overall, the findings of this study are in line with observations elsewhere in the former Socialist Federal Republic of Yugoslavia [22] and suggest that, as a result of significant vegetation regrowth, the changes observed over a period of time there has been land resilience and not degradation. The magnitude and speed of vegetation recovery in Montenegro indicates that the seemingly barren landscape has been induced by human pressure [22]. The potential for regeneration of vegetation and its impact on hydrology indicate the type of changes that may be expected in other areas of the world, if vegetation is allowed to regrow. As a consequence, decreasing of sediment supply is expected [2, 23, 26] which is in line with increased vegetation cover in the catchments. This opens perspectives for other Mediterranean countries that still suffer from desertification, as well as for other regions in the world with a similar bio-physical setting [22].

4. Conclusions

Many factors have influenced the development of erosion processes in the Krivaja River Basin. The most significant factors are the area's climate, relief, geological substrate and pedological composition, as well as the condition of the vegetation cover and the land use.

The values of (a)symmetry coefficient (0.88) indicates that there is a possibility of large flood waves in the river basin. The value of the G coefficient, which is 0.93, indicates a medium density hydrographical network. Maximum outflow (100 year event) from the river basin, Qmax, is calculated at 42 m^3s^{-1}.

The average value of the Z coefficient for the period 1970-2013 was 0.322. The river basin belongs in the „Destruction Category IV", according to the classification system of Professor Gavrilovic. Erosion process is weak, and the type is intrusive erosion. The real soil losses are 1205.46 m^3/year (132 m^3/km^2/year). Change of the land use in structure for the period of four decades (1970-2013), in the studied river basin, according to our analyses, decreased the soil erosion intensity for 3.43%.

It is recommended to undertake measures against the possibility of increasing soil erosion processes in some specific spots on the upper part of the river basin. To support more rapid recovery of vegetation and slow down the erosion processes, some biological protection measures need to be applied, together with technical ones - notably the use of shoulders and ditches to partition water fluxes at the land surface in the central and upper parts of the river basin. These would mitigate rapid runoff and unwanted transport of eroded materials. These measures would be further supported by better land use, including afforestation, reforestation and the renewal of grasses, shrubs and trees.

The restoration and erosion control measures will decrease degradation processes and will help rehabilitation of the landscape.

The authors of this study proposing the findings and approaches of this research to be used to develop soil erosion conservation programs for the study area of this River Basin, but also for the Polimlje watershed and the Region broader.

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Case study

THE HISTORY OF LAND CONSOLIDATION IN SERBIA

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Abstract: *Development of agriculture depends on many factors on which man may or may not have the impact. One of the parameters which is directly dependent of human will, and which is important for development of agriculture, is improvement of the structure of land property (several parcels owned by the same owner) in which is planned agricultural production. Land consolidation presents the measure that is traditionally used to regulate agricultural land and improve its structure. There is presumption that performing land consolidation began in the XIX century. In the second half of XX century works in carrying out the land consolidation were very intensive, so until 1990 land consolidation had been realized on ¼ of area of agricultural land.*

Along with the changing the structure of land property through grouping parcels and construction of infrastructural facilities, there were another measures carried out in order to improve life quality of farmers. Above all, it refers to the measures that have contributed to better economic and social position of farmers.

Further development of land consolidation is primarily determined by planned material resources for its purpose. If the goal of land consolidation project is to maximize the results (excluding material resources), it is necessary to implement changes that will allow it. Primarily, it is necessary to introduce changes to the existing legislation (in fields of agriculture and land consolidation), and then in the state administration organization and educational system. The particular section of the paper is devoted to the content of the proposed changes in this area.

Key words: *land consolidation, agricultural land, recommendations for development*

1. Introduction

Fragmentation of agricultural holdings in Serbia is the consequence of historical heritage and political changes which were frequent after the 18th century. Fragmentation of land parcels and their irregular shape significantly influenced the non-productivity agriculture. Land consolidation is a measure that has traditionally been used for the agricultural landscaping. The first land consolidations were reduced to the exchange of land through land swaps, and thus the properties grouped and created higher parcels. In these early consolidations have not been building rural roads or drainage systems and irrigation, so that the effects of consolidation were bad. In addition, insufficient training of personnel who conducted the consolidation has left its consequences. The application of technological solutions and need to be within the same cultural practices achieve the best possible conditions for the production and life on the country resulted in the complex land consolidation projects, which include the development of several sub-projects (field roads, canals, forest belts protection etc.).

The necessary condition for land consolidation implementation is that the record of ownership and state survey data (or property cadastre if these records are merged) exists. The reason that the first land consolidation projects of the Republic of Serbia were implemented on the territory of Vojvodina and much later in Central Serbia is availability of data on immovable property and rights. Most of the costs of land consolidation projects are cadastral works, including update of the registry or its development. Implemented land consolidation projects in Serbia can serve as a good practice example for countries that have maintained the owner rights and cadastre (separately or merge in one record). Through the implementation of land consolidation projects the state gets updated records and landscaped farms.

This paper describes the results of implemented land consolidation projects in the Republic of Serbia since 1860 and recommendations that will enable efficient implementation of land consolidation projects, the development of the techniques of consolidation and application of scientific achievements in practice.

2. LAND CONSOLIDATION THROUGH HISTORY

Since the beginning of 18th century there have been many changes that have the greatest impact upon the structure of farms and changing agrarian relations in the Republic of Serbia. These changes were most intense in Vojvodina. In the other parts of the country these changes were not as intense until the end of the World War II and the beginning of the implementation of agrarian reform.

Political situation in Vojvodina and the other parts of Serbia weren’t the same during the 18th and 19th century. Vojvodina is liberated from Ottoman Empire and annexed by Habsburg monarchy at the beginning of 18th century. The territory of the Republic of Serbia, which is located south of the Sava and Danube rivers (Central Serbia) was under Ottoman Empire until 1833. Vojvodina and Central Serbia became part of the same country – The Kingdom of Yugoslavia in 1918, at the end of the World War II.

The territorial division of Vojvodina (in the 18th and 19th century) at the border, district, provincial and the free royal cities [3] had a different rights and obligations that the residents of these areas had to the land (and land owners). Colonization Germanic and Hungarian population in middle 18th century caused the significant change in the structure of property rights. Despite all the changes in agricultural land management policy, Vojvodina had done land surveying and made land registry [3]. In 1774 Maria Theresa enacted a *Privilege* (Serbian: *Privilegija)* [3], an act that regulates relation between district (civil governmental unit) and state authorities, as well as the rights and obligations of citizens to the state. The *Privilege* is the first urbarium (act governing the obligation of paying land taxes). Regulated property relations and settled the land registry contributed to the consolidation the earlier in Vojvodina. In 1836 Habsburg monarchy adopted the *Law on Land Consolidation* (Serbian: *Zakon o komasaciji*) [3], which served as the legal basis for the land consolidation implementation. The first consolidation carried out in accordance with this law in Bačka in 1860 and in Banat in 1861 [3]. This law had a lot of changes. Version of this law from 1908 became part of the legal basis for land consolidation in Yugoslavia.

After the liberation from the Ottoman Empire, the population in Central Serbia could acquire ownership on the land that was previously cultivated. Land ownership acquired by the issuing of title deeds by the court, but organized land surveying and cadastre didn't exist until the early 20th century. General Directorate of Cadastre (Serbian: Generalna Direkcija katastra) of the Ministry of Finance [1] was established in 1919. The aim of the Directorate was to prepare the necessary regulations for implementing a cadastre, to take care of the cadastre establishment in areas where the cadastre didn't exist, and in other areas to maintain about cadastral data. Important year in the history of the development of cadastre and land consolidation in Serbia was 1929 when the state adopted the *Law on Cadastre* (Serbian: *Zakon o katastru*). By this law is regulated that the cadastre exists not only as an instrument for the land taxes assessment, but also for agricultural measures application. *The Land Registration Act* (Serbian: *Zakon o zemljišnim knjigama*) and other laws [3] that were intended to establish the technical (cadastre) and property (land registry) registrations in all country were adopted after 1930.

The lack of surveying and cadastre were the reason why the first land consolidation implementation in this part of Serbia was implementing between the two world wars. Professor Milan Andonović initiated the adoption of the law on land consolidation in the Kingdom of Serbia in 1901 [3]. Unfortunately, the proposed law model is not adopted. *The Law on Land Consolidation* for the regions Croatia, Slavonia and Dalmatia was adopted in 1902 [3], which has been applied over the next 52 years. In accordance with this law were implemented numerous land consolidation projects in Yugoslavia.

The newly created state, Yugoslavia, consisted of territorial units which had different legal bases. On the territory of the state there were two active laws which regulated land consolidation. In order to create a uniform law for the whole country, it was prepared the *Basement of the law on land consolidation* (Serbian: *Osnova zakona o komasaciji*) [3]. This document is not approved, but in 1925. Yugoslavia adopted the land consolidation carried out in accordance with the provisions of *The Law on Land Consolidation* (was adopted for the regions Croatia, Slavonia and Dalmatia) from 1902, and the *Law on Land Consolidation* (adopted in 1836) with modifications from 1908 [3]. The land consolidations were adopted in accordance with these laws until 1941.

The biggest changes in land ownership ensued between 1945 and 1953. Then were enacted legislations which enable the land confiscation for various reasons. These measures have further disturbed property relations and the structure of land parcels. In this way was created a specific type of ownership called the social ownership (held by the end of the 20th century).

Perception that land consolidation is capitalist measure leading to the strengthening of private property was characterized after the World War II, which wasn't in accordance with political ideology. In 1956 the state started with numerous land consolidation projects at the request of agricultural holdings in social assets. The aim of these projects was grouping of parcels and creation the conditions for economical production. During this period province governments adopted the laws in the province Vojvodina (1972) [3] and the province Kosovo and Metohija (1976) [3]. These laws regulated the land consolidation implementation in these provinces. The *Law on the use of agricultural land* (Serbian: *Zakon o korišćenju poljoprivrednog zemljišta*) [3] was adopted in 1981 for the territory of Socialistic Republic of Serbia. In accordance to with these three laws were implemented the land consolidation projects until 1990, when stopped with land consolidation project implementation [2].

3. RESULTS OF LAND CONSOLIDATIONS IMPLEMENTED TO 1990

The results of the first land consolidation projects that took place on the territory of Serbia were very modest. The reasons for this are not well-trained personnel who conducted the consolidation, but also organizational and technical problems. As the first land consolidation didn't include melioration, the effects of this consolidations implemented to improvement of agricultural production were not significant. Later, land consolidation became a measure for achievement the conditions for sustainable life quality for farmers. The development of technology enabled faster and more efficient implementation of land consolidation and achieving maximum impact and maximum savings of time and resources.

Table 1 shows the effects of land consolidation projects implemented to 1990 in terms of reduction of agricultural land, reducing the number of land parcels and to increase the area under the irrigation systems and roads.

Table 1: The effects of implemented land consolidation projects [3].

Land consolidation effects				
Territory	Area of agricultural land (%)	Number of parcels (%)	Area of channels (%)	Area of roads (%)
Serbia	-2.0	-65.1	59.6	26.0
Central Serbia	-2.9	-64.4	59.6	91.6
Vojvodina	-1.8	-66.0	59.6	9.2
Kosovo and Metohija	-2.9	-64.4	59.8	91.4

Reducing agricultural land after the land consolidation implementation is realized through allocations of land for common purposes, and for the construction of the road network and irrigation system. Areas under channels have increased by an average of 59.7%, while the surfaces under roads have increased by average 54.6%. Number of land parcels is reduced by approximately 65%. Reducing the number of parcels is shown in Fig. 1.

Reducing the number of parcels through the grouping led to an increase in surface area of new parcels. Increasing the surface of new parcels is performed both in social and private ownership. Table 2 shows the average surface of parcels before and after land consolidation in social and private ownership.

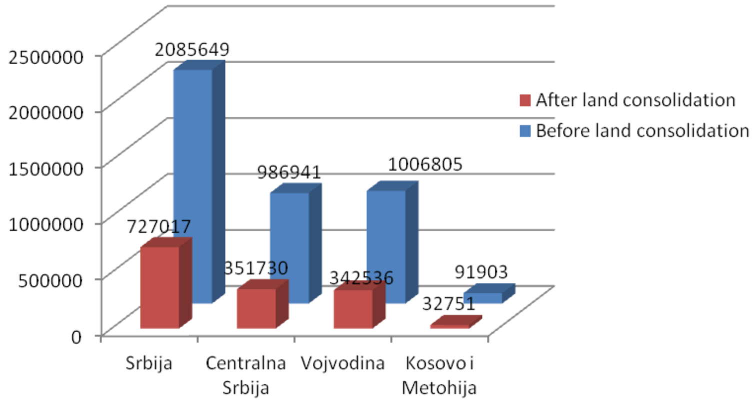

Fig. 1: Number of land parcels before and after land consolidation [3].

Table 2: The effects of land parcels consolidation [3].

Territory	Social ownership		Private ownership	
	Before land consolidation (ha)	After land consolidation (ha)	Before land consolidation (ha)	After land consolidation (ha)
Serbia	1.09	7.15	0.24	0.61
Vojvodina	1.50	10.8	0.67	1.40

In addition to these effects, which are numerically measurable, the effects of consolidation are among those whose significance is difficult (or impossible) to determine:

– **Allocation of land for common purposes**. Under the appropriation of land for common purposes involves the extraction of land for the construction of facilities that contribute to quality of life and work in rural areas: road and channel network, markets, schools, hospitals, cemeteries, land for national important object constructions etc.

– **Changing the boundaries of the urban construction area** (of the formation of the urban construction area). In this way are made the basis for urban planning and planned development of settlement.

– **Protection of the environment**. The formation of protective forests realizes the effects of reducing the effects of weather on crops and creates conditions for the survival of many plants and animals. In addition, significantly improves the quality of air.

– **Reduction of rough surfaces**. The implementation of land consolidation projects and reducing the number of land parcels reduces the area under the parcel boundaries (which is often overgrown with grass and verts and it is impossible to cultivate).

– **Regulation of waterways**. The construction of new and reconstruction of existing drainage network create conditions for regulating the requirements for drainage and irrigation of agricultural land. In addition, regulation of existing waterways can reduce the risk of flood-and-dry. In this way, in addition to crop, plants and animals residing in rivers are protected.

All of the above effects and the size of their influence are dependent on environmental conditions and the needs of the local community. The structure of mentioned effects demands forming of the multidisciplinary team for land consolidation implementation.

4. LAND CONSOLIDATION TODAY

Until 2011 in Serbia, 897 cadastral municipalities were arranged by the land consolidation. A total area of these municipalities is 1.892.624 hectares, which represents about 25% of the total agricultural land in Serbia. Surfaces arranged by land consolidation constitute about 60% of agricultural land in Vojvodina, about 9% in Central Serbia and about 5% in Kosovo and Metohija [2].

After 15-years break, land consolidation projects in Serbia started again since 2005. The first project of land consolidation in Serbia after a long break was implemented in a way that the abundant practice of land consolidation was not applied – based on a voluntary grouping of land parcels. The project is called "*Support to the preparation of the national strategy of land consolidation and land consolidation pilot project in Serbia*" (Serbian: "*Podrška pripremi nacionalne strategije komasacije i pilot projekat komasacije u Srbiji*") and was founded by the Food and Agricultural Organization – FAO of the United Nations [4]. The aim of this project was to prepare a national strategy of land consolidation, and a pilot project was implemented in Velika Moštanica (Municipality Čukarica, Belgrade) [4]. Land consolidation projects which realization started after 2006 were financed from funds raised from state owned land leasing.

Currently, land consolidation projects are active in the six cadastral municipalities: Selenča, Pavliš, Despotovo, Bački Petrovac, Kulpin and Središte [2]. With the implementation of land consolidation projects in these cadastral municipalities shall be established the real estate cadastre. These six cadastral municipalities were without real estate cadastre (an unique evidence about immovable properties and rights related to them) at the end of 2012, ending the project "*Real Estate Cadastre of the Republic of Serbia*".

4.1. Legal framework

Implementation of land consolidation projects in the Republic of Serbia is responsibility of Ministry of Agriculture. Organizational structure of the Ministry of Agriculture makes five Directorates. One of them is Directorate for agricultural land. Directorate for agricultural land is responsible for the protection, arrangement and management of state owned agricultural land.

The legal basis, which regulates the land consolidation in the Republic of Serbia, is the *Law on Agricultural land* [6]. Under this law, the land consolidation is carried out due to the high fragmentation and irregular shaped agricultural land parcels cannot rationally use or together with the implementation of agro-technical measures which shall improve conditions for agricultural production (construction of a drainage system and irrigation, construction of road network etc.). All activities related to the arrangement and use of agricultural land in the Republic of Serbia shall be conducted in accordance with the Agricultural base in the Republic of Serbia, and the Agricultural base of the local government.

Draft version of new Law of Agricultural land (which is in the process of adoption) proposed amendments to the reasons for the conducting of land consolidation that include the tendency for increasing agricultural parcels and the need for improving the conditions for living and working.

The legal basis for carrying out a consolidation is also *Law on State Surveying and Cadastre* [5], which defines the scope of work of surveying staff in land consolidation project realization. Basis for land consolidation realization are also sub-legal documents that governing the cadastral classification and quality evaluation, as well as the means for real estate data collection, making surveying elaborates and others.

The result of the implemented project "Support to the preparation of the national strategy of land consolidation and land consolidation pilot project in Serbia", is the document *Strategy for land consolidation in the Republic of Serbia,* which has not been adopted yet [4].

4.2. Land consolidation models

Under the current legislation, there are two types of land consolidation which regulates the agricultural land:

- Comprehensive land consolidation
- Voluntary grouping of land [6].

Comprehensive land consolidation is carried out in one or more cadastral municipality or part of cadastral municipality. Voluntary grouping of land shall be his consolidation for rational use. Voluntary grouping of land can be implemented through the cadastral municipality or part of cadastral municipality. It is necessary that proposal for voluntary grouping of land was initiated by the ten owners of the land (for private owned land) or by one owner (for state owned land) for decision making by local self-government assembly.

Draft version of Strategy for land consolidation in the Republic of Serbia have identified three land consolidation models that the best suit the conditions and needs in Serbia [4].

Comprehensive mandatory land consolidation by which is identical to land consolidations that were conducted for decades in the Republic of Serbia (including rural development measures, the construction of irrigation systems, the prevention of soil erosion, construction of local infrastructure, etc.).

Land consolidation as part of the investment project represents implementation in the area of large infrastructure projects, in order to regulate the surface area outside the expropriation zone.

Simple voluntary land consolidation – is based on the agreement of the owners about the exchange and aggregation of land parcels. Voluntary land consolidation is a framework for the implementation of supply and demand in the real estate market.

Form of land consolidation, which was introduced with amendments to the legislation in 2011, is urban land consolidation. Urban consolidation is an efficient measure for urban land arrangement, according to similar principles and rules that apply for agricultural landscaping.

5. RECOMMENDATIONS FOR FURTHER DEVELOPMENT OF LAND CONSOLIDATION

Further development of land consolidation depends mainly on improvement in key areas: legal framework, land policy, organizational framework and personnel. Proposed measures that can contribute to the further development of land consolidation are set out in Table 3.

Table 3: Recommendations for land consolidation development

DOMAIN	ACTIVITY	PROPOSED MEASURES
LEGAL FRAMEWORK	Adoption of new and amended existing legal framework	Law on the public administration organization; Law on Agricultural land; Law on land consolidation; Law on land funds; The strategy of land consolidation; Law on basic property relations (clearly defined types of property rights)
LAND POLICY	Long-term and short-term plans for agricultural land management	Define a clear agricultural land management policy
	State owned land (Forming of land banks)	Changes in state owned land management policy; Allow the sale and purchase of state owned land in order to enlarge the parcels (private and state parcels); Include state owned land in land consolidation projects; Forming of land banks (responsibility, organization, financing)
	Abandoned land	Definition of abandoned land; Mechanisms for abandoned land detection; Abandoned land management policy
	Land consolidation associated with other projects	Land consolidation under the restitution; Land consolidation under the construction of infrastructure facilities; Land consolidation in the asset management company in bankruptcy
	Stable source of financing	Ensure a stable and secure sources of financing that will enable long-term planning of financing arrangement of agricultural land
ORGANIZATIONAL FRAMEWORK	Clearly define the roles and responsibilities of all participants in carrying out land consolidation projects	Clearly define the roles and responsibilities through legal and sub-legal documents Give a greater authority to the Directorate for agricultural land in the planning and monitoring of land consolidation projects
PERSONNEL	Education and science	Specialized studies; Seminars; Conferences; Professional practice; Projects

6. Conclusions

The existence of evidences of real estates and related rights is the basis for the implementation of land consolidation projects. It is necessary to modernize the cadastre that land consolidation projects could be more successfully implemented. The period after 1988 is characterized by large investments in the development and modernization of the cadastre in Serbia. Through implementation of the real estate cadastre project, unique evidence about real estates and related rights has been achieved for the whole country. The next important step that will allow landscaping in order to increase agricultural production is updating real estate cadastre.

A big obstruction to achieving better effect of land consolidation is the non-inclusion of the state owned land in land consolidation projects. It is necessary to allow the state to buy and sell agricultural land. This way, interested farmers would expand their farms and those who want to steal the land can sell it the state.

Today, the land consolidation projects are financed from the fund accumulated from the state owned land lease. The rent has no fixed value, but is subject to auctioning. In this way, only farmers who have enough money to compete are renting state owned agricultural land. Although this method of issuing land makes more money to the state, is devastating the "smaller" farmers and provides no incentive for the development of agricultural production. It is necessary to change the agricultural land management policy and seek to maximize profit from renting land lease, and encourage farmers to lease and buy land.

Assessment of the Ministry of Agriculture is that about 5% of arable land is abandoned. It is necessary to take measures to detect abandoned land, to identify holders of rights to abandoned land and bring purpose of this land. Good practice examples of this are land banks, which exists from 1841 year in some European countries.

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Case study

ANALYSIS OF THE EVOLUTION OF LANDSCAPE AND LAND USE IN A GIS APPROACH

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Abstract *The use of Geographical Information Systems facilitates spatial analysis and allows the understanding of the evolutionary processes that occurred over the years and have led to the current conditions. Thanks to a comparison between an historical cartographic map with recent ortophotos, it was possible to evaluate the meaningful elements present in an area and their changes over time. A compared analysis, started early 1800, found that the study area, mainly its rural and forestry land, have been affected by deep transformations, due to natural events, human intervention, and changes in natural cycles, that resulted difficult to understand. The historical map represents the entire municipality of Ruoti (Basilicata Region, Southern Italy), traditionally devoted to arboreal cultivation or wood-sheep farming,. The map reports the town and the surrounding area in the Year 1812, showing the main rivers, the land use of the area, the different type of vegetations, expressed with different colors and symbols.*

The spatial analysis of this study area showed a succession of land use changes, influenced by the modern cultivation techniques, while vegetation changes give variations of the agro-forestry landscape over the years, and cultivation conversion caused a loss of CO_2 fixation value.

Key words: *GIS, historical map, land use, carbon balance*

1. INTRODUCTION

Multi-temporal analysis of land, with the support of GIS and historical document, is a very important tool for monitoring landscape diversity and for investigating changes in vegetation and landscape structure. In recent years, technical and spatial analysis of landscape have been developed. The issues of historical landscape analysis and the influential driving factor of landscape development provide an essential basis for tackling current environmental questions in spatial planning [3]. The *landscape* should be understood as a dynamic and open system, where biophysical, social and economic factors interact to define the current structure. The Knowledge of the historical landscape development should therefore be the starting point for long-term landscape monitoring [8]. The objective of this work is an analysis of the land use over two centuries in an area that represents the Municipality of Ruoti. Through a comparison of chronologically different land cover maps it was therefore possible to assess and quantify the CO_2 variation in this area.

2. MATERIAL AND METHODS

2.1 Study Area

The study area is represented by Ruoti Municipality (55 km^2) located in the central-western part of Province of Potenza, in Basilicata Region, Southern Italy. The territory has a considerable morphological variability, with the presence of soils of different age. This area is characterized by an hilly territory, the elevation being in the range 400 - 1000 m.a.s.l..

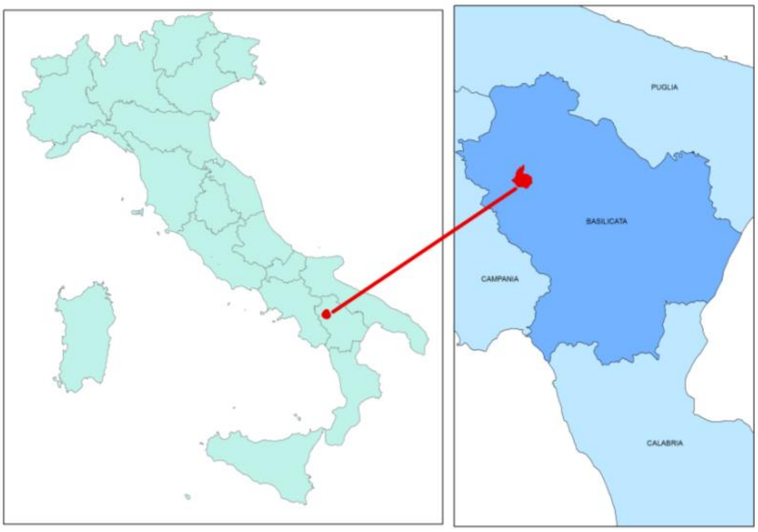

Fig. 1: Study Area.

The study area is crossed by the most important rivers present in this territory: the "Fiumara di Avigliano" and is bounded in the south by the "Fiumara di Ruoti". Both rivers are part on the hydrographic basin of the river "Sele". The geomorphological survey, however, has shown the presence along the slopes of several landslides. The study area is predominantly occupied by agricultural land (40%), forest and semi-natural areas (57%) and artificial surfaces (3%). The high-hilly landscape of the study area is characterized by an arable land, present especially in the hills, wide pastures in the north-area and vineyards. The mountains are covered with rich woods consisting mainly of underwood , such as fir-wood, with pieces of "Abies Alba" (a biotope surveyed by Italian Botanical Society).

2.2 Cartography and data

Land use changes in the study area were examined in two time periods: years 1812 and 2012. The historical information, dated 1812, derived from an historical map preserved in the "Archivio di Stato" (State Archives) in Potenza and from information wrote in the "Catasto Napoletano" (Neapolitan Cadastral Office) dating the Year 1812.

Fig. 2: Historical cartographic map year 1812.

The historical maps were produced in border disputes by legal experts and technical part, they represented a comparison between a documentary tradition, such as diplomatic writings, and feudal judicial and investigation of the soil. The map reports the town and the surrounding area, and shows the main rivers in the area. In the north part there is the presence of lands that can be classified as arable land, in the central part of the territory there is the alternation of olive groves and vineyards. The other part of land consists of forest and underwood. The maps was firstly scanned and digitized within a Geographic Information System, than the land use categories were extracted. The "Catasto Napoletano" expressed a breakdown of the agricultural and forest land in 4 time periods:

1753, 1812, 1929, 1959. In relation to year 1812, the data derived by a land description are based on the reports of the holder and on valuation of different types of vegetation. At the end of the original table it was written that data of agricultural and forestry lands are expressed without a specific use finalization, the so-called "Partite speciali" (Special lots). So, the total area expressed by the data of the Catasto Napoletano is not the same as the total area expressed by the determination of land use with the historical map.

2.3 Data analysis

The historical map was geo-referenced through a sequence of rectification and referencing procedures with control points on the map at know locations. Thanks to the different simbology present on the map it was possible the identification of the various types of land use. To determine land use of year 2012 recent digital ortophotos were utilized. Aerial photos were scanned and converted into a digital image and subsequently it was possible the identification of a great number of elements in the area: land use, farms hydrographic network, infrastructures, etc.

3. Results and discussion

3.1 Land use analysis

From the superposition of different base maps it was possible to identify the different categories of land use. The number of classes identified has increased, mainly due to the improved detail provided by the base. The results of the territorial analysis are expressed in the following table.

Table 1 represents, for each data and for each different cartographic support, the landscape use; the comparison has enabled the analysis of land changes from 1812 to present days, covering a time period of 200 years, giving information about the historic persistence of soil use typologies along with their time-driven modifications. Dominant land use typologies of the site have been grouped in order to better compare the output data through a more evident highlighting of variations in time.

Visualizing spatial data expressed in Fig. 3, we can observe a decrease in the arable land, a reduction of forested surfaces and an increase of continuous and discontinuous urban fabric. The urbanized area has undergone a substantial increase especially after the Second World War. As reflected by a widespread tendency in different areas of the region, the areas for agriculture and crops have been significantly reduced, almost halving the benefit of natural areas in terms of their role in the equilibrium of the natural ecosystems.

Table 1: Land use analysis from 1812 to 2012.

	"Catasto napoletano" 1812		Historical map 1812		Ortophotos 2012	
Land Use	Area ha	Share %	Area ha	Share %	Area ha	Share %
Arable lands	2527	51	1683	31	1541	28
Fluvial zone	0	0	205	4	126	2
Vineyard and Olive groves	341	7	723	13	145	3
Forest	1973	40	1903	35	1697	31
Underwood and Oaks	8	0	405	7	1320	24
Chestnut groves, pastures and natural land	124	2	125	2	444	8
Reed beds and vegetable gardens	11	0	0	0	0	0
Urban fabric and discontinuous urban fabric	0	0	85	2	231	4
Surface "M.s."	38	1	0	0	0	0
Agricultural land with vegetation	0	0	375	7	0	0
	4986		5504		5504	

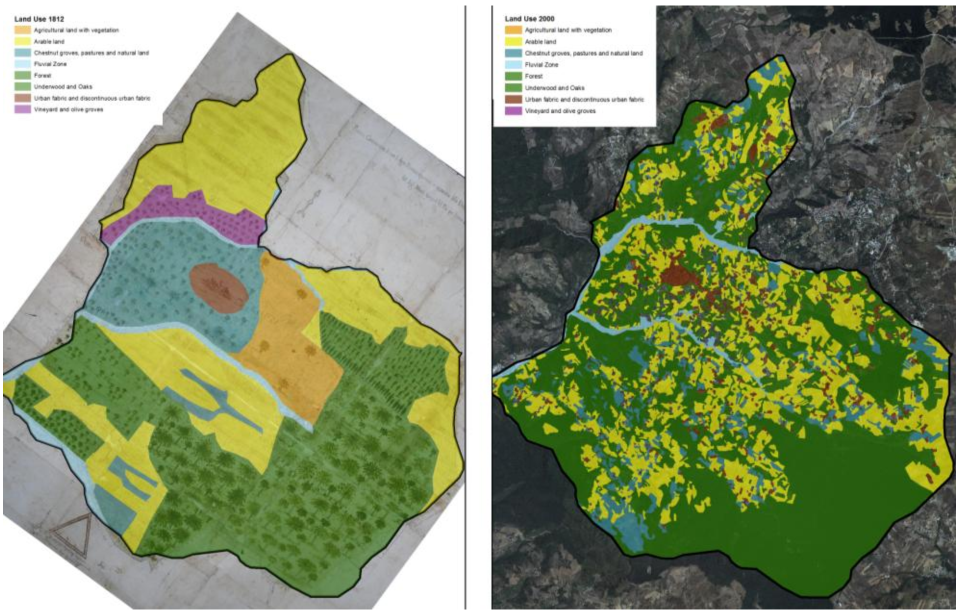

Fig. 3: Land use maps for different time periods – Left: the Historical Map. Right: the recent ortophotos.

3.1 Carbon dioxide balance

With the aim to quantify the effect of land use changes on the environment, with a special emphasis on air quality, the CO_2 time variation connected with land use was estimated. CO_2 fixation rates were calculated through adopting the user-friendly CO2FIX V.3.2 model [5] tool for the dynamic estimation of the carbon fixation potential of forest management, agroforesty and afforestation projects. CO2FIX V.3.2 is a multi-cohort ecosystem-level model based on carbon accounting of forest stands, including forest biomass, soils and products. Carbon stored in living biomass is estimated there with a forest cohort model that allows for competition, natural mortality, logging, and mortality due to logging damage. Soil carbon is modeled using five stock pools, three for litter and two for humus. The dynamics of carbon stored in wood products is simulated with a set of pools for short-, medium- and long-lived products, and includes processing efficiency, re-use of byproducts, recycling, and disposal forms. The model CO2FIX V.3.2 estimation of the total carbon balance of alternative management regimes in forests is disconnected in age, and therefore has a wide applicability for both temperate and tropical conditions [5] and the conditions for European Countries [7].

The CO2FIX model was developed as part of the “Carbon sequestration in afforestation and sustainable forest management” (CASFOR) project, which was funded by the European Union INCO-DC program. [6]. CO2FIX is a carbon book-keeping model that simulates stocks and fluxes of carbon in (the trees of) a forest ecosystem, the soil, and (in case of a managed forest), the wood products. It simulates these stocks and fluxes at the hectare scale with time steps of one year [4]. Some of the results of CO2FIX have been used in the IPCC 1995 climate change assessment. The estimated biomass concerns to crop at maximum production levels, not taking into account the entire length of the cycle (for example poly annual crops).

In order to initialize the model, different analysis parameters were used. The assumptions that were made were consistent with the software input characteristics [6] and the local area characteristics [2]. For forestry area the following characteristics were used: tree species, area, age, dominant height, standing volume, growth class and the coordinate of the stand.

Woodland in the study area is represented by tall oak trees, with prevailing *Quercus cerris*. Rotation length is 80 years with maximum biomass in the stand equal to 2000 Mg/ha. The allocation factor for foliage, branches and root production were taken from existing CO2FIX runs for comparable species. The turnover (annual rate of mortality of the biomass component) was evaluated in 0.3 for foliage, 0.06 for branches and 0.05 for roots.

The soil organic matter compartment consists of dead wood, litter layers and stable humus in the soil. On the basis of this analysis, a total carbon stock ranging from 32 to 134 Mg/ha and an average atmospheric carbon fixation approximately equal to 25 MgC/ha/yr were estimated.

In the study area, the orchard areas are generally vineyards with rare presence of olive grove. For the purpose of CO_2 calculation, the orchard area was compared to tall trees forest with a rotation of 20 years and periodical removal of organic matter through agronomic practices like pruning, comparable to a turnover (annual rate of mortality of the biomass component) of 0.3 for foliage, 0.07 for branches and 0.04 for roots.

In an orchard, carbon balance depends on the intrinsic structural and morphological characteristics of each species and it is also influenced by population density, rearing system, and especially on the canopy and aboveground and underground woody organisms. Moreover, in the case of young plantation, canopy has to provide for a relatively small amount of branches and roots and, consequently, primary production is net and the surplus of organic matter increases every year up to maturity when dry matter increases over time and subsequently tends to zero [11]. Based on such a principle, it is possible to estimate the average yearly fixation of atmospheric carbon as being equal to 7.25 MgC/ha/yr for the orchards, to 2.75 MgC/ha/yr for shrubland and to 3.6 MgC/ha/yr for arable land.

On the other hand, urban areas represent a source of CO_2 emission from both municipal and industrial combustion; a yearly amount of 15.0 MgC/ha/yr of CO_2 release into the atmosphere was therefore estimated on the basis of a report on the environmental state of Basilicata Region [1].

All the above-mentioned values of average atmospheric carbon fixation were adopted for each one of the two time periods (Years 1812 and 2012).

The data resulting from the implementation of the GIS gave the values reported in Table 2 expressed in terms of areas occupied by the different vegetation typologies and, applying their respective CO_2 fixation rates, in terms of absolute values of annual fixation of CO_2. The fixation of CO_2 does not include the effects of the agricultural machinery, supplies and transportation on CO_2: in woodland these factors are almost absent, while in case of orchard and arable land they depend strongly by crop techniques, and in some cases are negligible.

Table 2: Annual fixation of CO_2 in the study area.

Year	Woodland		Orchard		Shrubland		Arable land	
	Area ha	Annual fixation MgC/ha/yr	Area ha	Annual Fixation MgC/ha/yr	Area ha	Annual Fixation MgC/ha/yr	Area ha	Annual Fixation MgC/h a/yr
1812	2513	62834.15	723	5241.11	125	343.89	2058	7407.84
2012	1823	45579.68	145	1049.51	1320	3628.83	1986	7147.98

Table 3: Urban and total annual fixation of CO_2 for the studied areas.

Year	Urban		Total	
	Area ha	Annual fixation MgC/ha/yr	Area ha	Annual fixation MgC/ha/yr
1812	85	-1270.01	5503.73	74556.98
2012	231	- 3459.71	5503.72	53946.29

Examining Table 2 and Table 3, in the investigated scheme it is clear that the greatest changes in land use occurred after the abandonment of large areas that over time have become shrubby, going from 125 hectares in 1812 to 1320 hectares in 2012, accompanied by a strong expansion of inhabited areas, going from 1.5% to 4.2% of the total surface.

The percentage decrease in orchard was equally considerable with decreases reductions increased from 13% to 2.5%.

The arable land has remained almost unchanged, while the forested area also suffered a sharp contraction (about 28% lower, form 2513 hectares in 1812 to 1823 hectares in 2012).

As a result of the different performance in terms of CO_2 fixation concerning the investigated study area, all these land changes caused progressive decrease in carbon dioxide sequestered by the biotic agents embedded in the soil.

We can finally argue that the fixation of land carbon in Year 1812 was higher than in more recent periods, and that during time the land carbon balance worsened: the cultivation conversion occurred during time caused a constant loss of CO_2 fixation value [6] while heavy emission of greenhouse effect gas in the atmosphere by urban settlements were at the same time increasingly growing.

This pattern could be considered a typical situation also for many other areas located in Southern Italy or even elsewhere this approach seems to be considered as an useful tool for the planning and management of the rural landscape and environment: the study case showed that a sound planning in agricultural activities could significantly contrast the release in the atmosphere of CO_2 deriving from the diffusion of anthropic activities.

4. CONCLUSIONS

Under the general framework of the territorial analysis, aimed to constitute a suitable support for a proper planning activity, it is extremely important to know which were the evolutions that changed the landscape over the years. This analysis has shown the differences, in term of land use and in terms of CO_2 fixation, that have occured in the Municipality of Ruoti, starting from 1812 to the present. Human development causes an environmental pollution determined by the urban settlements and their activities. The use of this approach for other environmental factors, such as water, soil etc., would lead to a more comprehensive understanding of landscape development dynamics through its principal environmental components, contributing to the proposal of production oriented politics that achieve compensation of natural balance alterations, and a real application of the concept of sustainable development.

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Original scientific paper

SUBSTRATE ADDITIVE FOR BIOLOGICAL DEPURATION

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Abstract. *The following study presents the results of testing of a substrate liquid added to a pre-existing system of biological filtration process air of a composting plant. The substrate under test is a mixture of micro and macro nutrients useful to improve the efficiency of degradation in the cases of degradable pollutants from microbial metabolism in the presence of a ratio C : N : P equal to 200 : 10 : 1. The tests were conducted in the field by applying the substrate in liquid form to a biofilter present in a plant for composting. The biofilter involved in the trial receives the effluent gases captured from the section of accelerated bio-oxidation system. The distribution of the substrate was carried out manually above the filter surface and the quantity of substrate used has been established in relation to the pollutant load input to the garrison to environmental and chemical-physical characteristics of the filter material. The effect of the use of the substrate was evaluated in terms of concentration of microorganisms in a* cm^3 *of filter material and the method used for this measurement was that established by Standard EN ISO 6222 of 1999.*

Key words: *degradable pollutants, biological filtration, biofilter, composting plant, microbial metabolism*

1. INTRODUCTION

The biological purification of flue gases is important in case of biodegradable substances. The decomposition of the pollutants is carried out by microorganisms that colonize a solid substrate support [7]. Support materials most commonly used are: wood chips, bark, peat, heather, and other similar materials, whether or not mixed together [11].

To ensure optimum operation of the biofilter [1] it is necessary to be the best conditions to promote the activity of microorganisms:

• humidity;
• pH;
• temperature;
• organic substance in the substrate;
• adequate time of contact between the effluent and the, material [5, 12].

For air that passes through the biofilter must be guaranteed a minimum contact time equal to about 60 seconds, equivalent to a maximum volumetric loading of 60 m^3 of air per hour per cubic meter of biomass filter [2]. The biofilter is constituted by biologically active material, resistant to compaction, with a good water retention capacity [9]. The moisture content should be maintained between 50% and 70%, it is good practice to irrigate the surface of the biofilter, humidify the incoming air and remove any drainage.

Fig. 1: Particular composition of the biofilter used.

The pH must be between 5 and 8.5 and should be compensated for any phenomena of acidification related to products that are formed during the biological oxidation. The temperature of the air introduced should preferably be between 10° and 45° C to remain in the optimal range of microbial growth without phenomena of excessive drying [6].

The tests were conducted for a period of 2 months with the preparation of an initial test used as proof "time zero" without the use of substrate.

The results obtained from extractions and microbial counts have shown that the use of the substrate has influenced the performance of the microbial population within the filtering mass according to the steps shown below:

1. the initial average concentration (test t_0) resulted into a value of $400 \bullet 10^2$ CFU;
2. the average concentration after 15 days (test t_1) by the application of the substrate resulted into a value equal to $2800 \bullet 10^3$ CFU;
3. after 30 days (test t_2) the value was equal to $7500 \bullet 10^3$ CFU;
4. after 45 days (test t_3) the value was equal to $1800 \bullet 10^3$ CFU;
5. after 60 days (test t_4) the value was equal to $100 \bullet 10^3$ CFU.

2. MATERIAL AND METHODS

The tested product allows a rapid rise in the concentration of microorganisms in the unit volume of treated matrix, adding a substrate composed of micro and macro elements of water wetting and is dosed in order to obtain a CNP ratio equal to 200:10:1 [3].

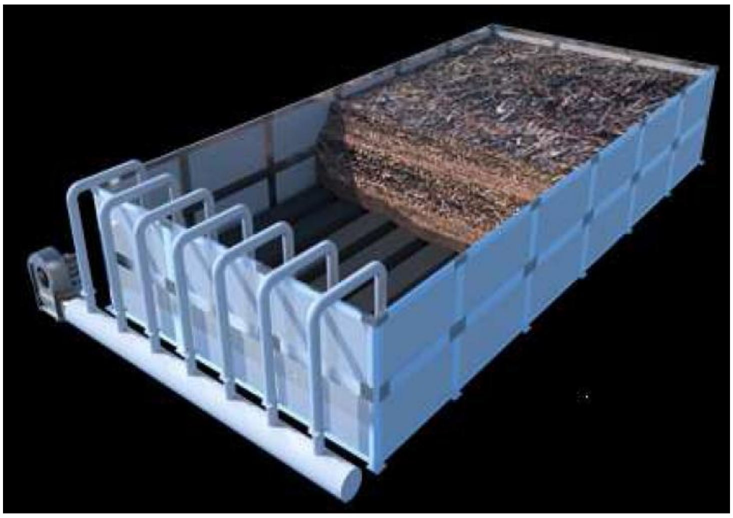

Fig. 2: Schematization of purification process by the use of the biofilter.

2.1 Tests performed

The checks carried out to the substrate have been completed in 2 times. Were initially drawn to scale within a laboratory operating conditions of a biofilter and then it turned to field trials of a bio-active in a plant for compost quality.

2.2 Tests in laboratory

Each of laboratory models has been realized by means of a bath in plexiglass with the double bottom, for the forced passage of air and the collection of the drain system. For the wetting of each of the systems has been used a volume of 3 liters of the drain of a biofilter after a characterization of the parameters COD, BOD, N and total sulfur compounds.

The 3 models have been filled with a volume of 0.125 m^3 and wood chips were used to obtain respectively:

- the model 1 for the reference test, known as "white";
- the model 2 for test n. 1, called "test concentration to 1% by volume";
- the model 3 for test n. 2, called "test a concentration of 5% by volume".

To evaluate the efficiency of the system was measured in each of 3 models the concentration of CFU per cm^3 of wood chips and the parameters COD, BOD, total N and sulfur compounds to the drainage system.

The measurements on each of the 3 models were conducted in n. 5 periods:

- at time zero, before the application of the substrate, "time 0";
- at 15 days from the application of the substrate, "time 1";
- at 30 days from the application of the substrate, "time 2";
- at 45 days from the application of the substrate, "time 3";
- at 60 days after the application of the substrate, "time 4".

2.3 Field testing

For field testing was added to the product, at concentrations equal to 1% by volume, of the biofilter irrigation water present in a plant for compost quality [8, 10].

To evaluate the efficiency of the system was measured before and after the addition of the substrate the concentration of CFU per cm^3 of wood chips and the parameters COD, BOD, total N and sulfur compounds to the drainage system.

Measurements were conducted in 5 periods:

- at time zero before the application of the substrate, "time 0";
- at 15 days from the application of the substrate, "time 1";
- at 30 days from the application of the substrate, "time 2";
- at 45 days from the application of the substrate, "time 3";
- at 60 days after the application of the substrate, "time 4".

2.4 Determination of total viable count in water and wastewater

This test method is based on a procedure EN ISO 6222:1999.

Water of all kinds invariably contain a variety of microorganism [4] derived from various sources such as soil and vegetation and estimation of the overall numbers provide useful information for the assessment and surveillance of water quality. Most bacteria capable of growth in potable water and natural surface waters in temperature climates will grow better in culture media at 22°C than at higher temperatures. Organism that grow best at 37°C usually grow less readily in potable water and are likely to have gained access from external sources particularly of human or animal origin.

These two groups of organism are counted separately of ground water sources and the efficency of water treatment process such as coagulation filtration and disinfection and provide an indication of the cleanliness and integrity of the distribution system.

In pool waters, the colony count at 37°C is used as these organism are most likely to have been derived from the bathers and are a better measur of the disinfection of the pool water.

The main value of colony counts lies in the detection of changes from those expected, based on frequent long temr monitoring. Any sudden increase in the count can be an early warning of serious pollution and calls for immediate investigation. It is therefore important that the same tecnique and media should always be used to examine a given water sample. For the purpose of this method the following definition applies: colony count (culturable micro-organism), various synonyms are frequently used instead of "colony count", these include heterotrophic colony count, viable count, plate count and culturable micro-organism. Measured volumes of the sample or dilutions of the sample are mixed with molten yeast extract aqar in sterile Petri dishes and incubated under the conditions specified. Calculate the number of colony forming units (CFU) per millilitre (ml) of the sample from the number of colonies.

2.5 Procedure with reagents and apparatus

Reagent that occured in these tests are:

- milli-Q water, pour plate agar, ringer solution.
- waterbath, 45°C +/- 1°C;
- boiling waterbath;
- incubator, 22°C +/- 1°C, 37°C +/- 1°C;
- petri dishes;
- autoclave;
- colony counter.

Aseptically measure a 1 ml volume of sample or dilution into a Petri dish using a automaic pipettor and sterile tips. Aseptically pour approximately 15-20 ml of melted extract (PCA) which has been cooled to 45°C, into the Petri dish. The time elapsing from when the prepared dilution or neat sample in inoculated into the Petri dish and the moment when the mediun is added shall not exceed 15 minutes.

Immediately mix the sample and agar carefully for at least 10 seconds, by rotating to the Petri dish clockwise three times, anti-clockwise three times and clockwise a further three times. It is essential to keep the Petri dish flat on the bench throughout the procedure.

Allow the agar to set. Invert the Petri dishes and incubate.

3. Results and discussion

Calculate the colony count as follow:

$$\text{colony count (ml of water)} = \frac{\text{numbers of colonies}}{\text{volume tested}} \text{ x dilution factors}$$

3.1 Results of tests in laboratory

The obtained results will be shown in schematic form in order to make the data acquisition more immediate.

Table 1: Results of the parameters analyzed at time zero "white".

Parameter	Units	Time zero "white"				
		Time 0	Time 1	Time 2	Time 3	Time 4
CFU/cm^3	CFU	$70 * 10^2$	$100 * 10^2$	$110 * 10^2$	$90 * 10^2$	$100 * 10^2$
COD	mg/l	1060	1100	1000	1075	1110
BOD_5		880	910	950	900	950
Total N		1200	1310	1150	1220	1200
Sulfur compound		65	50	55	50	55

Table 2: Results of the parameters analyzed for test concentration to 1% by volume.

Parameter	Units	Test concentration to 1% by volume				
		Time 0	Time 1	Time 2	Time 3	Time 4
CFU/cm^3	CFU	$85 * 10^2$	$50 * 10^3$	$320 * 10^3$	$120 * 10^3$	$100 * 10^3$
COD	mg/l	1100	1005	1090	950	930
BOD_5		930	1095	1265	1200	1250
Total N		1100	1050	1000	975	990
Sulfur compound		60	35	40	35	35

Table 3: Results of the parameters analyzed for test concentration to 5% by volume.

Parameter	Units	test a concentration of 5% by volume				
		Time 0	Time 1	Time 2	Time 3	Time 4
CFU/cm^3	CFU	$85 * 10^2$	$50 * 10^3$	$240 * 10^3$	$300 * 10^3$	$260 * 10^3$
COD	mg/l	1150	1100	1100	990	975
BOD_5		1000	1250	1425	1395	1400
Total N		1065	995	845	810	800
Sulfur compound		60	40	25	30	30

In the following figures it can be seen, in graphic form, the pattern of results of the experimental tests.

3.2 Results of field testing

The obtained results will be shown in schematic form in order to make the data acquisition more immediate.

Table 4: Results of the parameters analyzed for field testing.

Parameter	Units	Field testing				
		Time 0	Time 1	Time 2	Time 3	Time 4
CFU/cm^3	CFU	$400 * 10^2$	$2800 * 10^3$	$7500 * 10^3$	$1800 * 10^3$	$100 * 10^3$
COD	mg/l	1830	1705	1770	1940	1735
BOD_5		1250	1990	2100	1845	1770
Total N		1300	1410	1260	1035	940
Sulfur compound		70	65	45	50	30

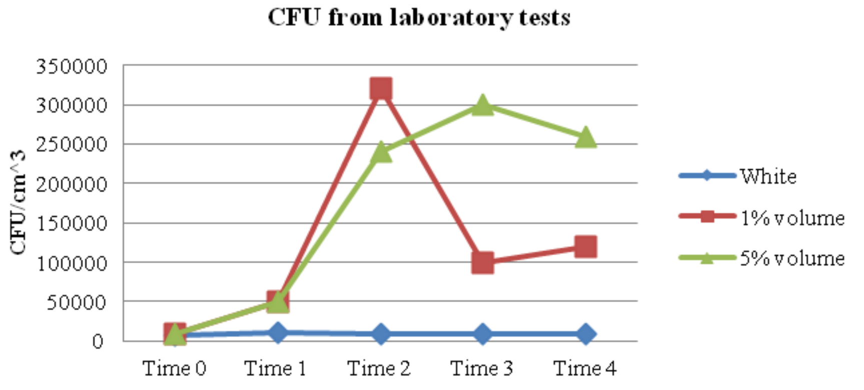

Fig. 3: Results of CFU from laboratory tests.

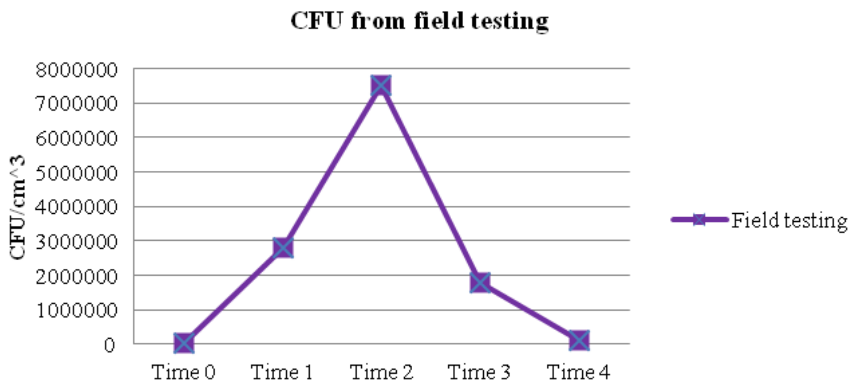

Fig. 4: Results of CFU from field testing.

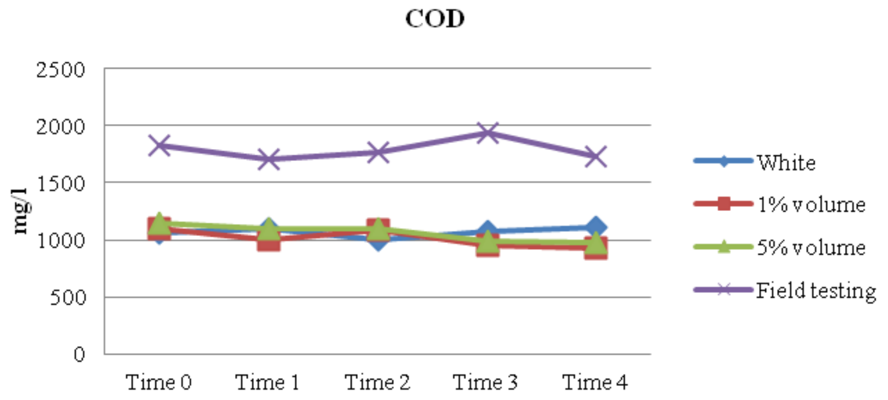

Fig. 5: Results of COD from laboratory tests and field testing.

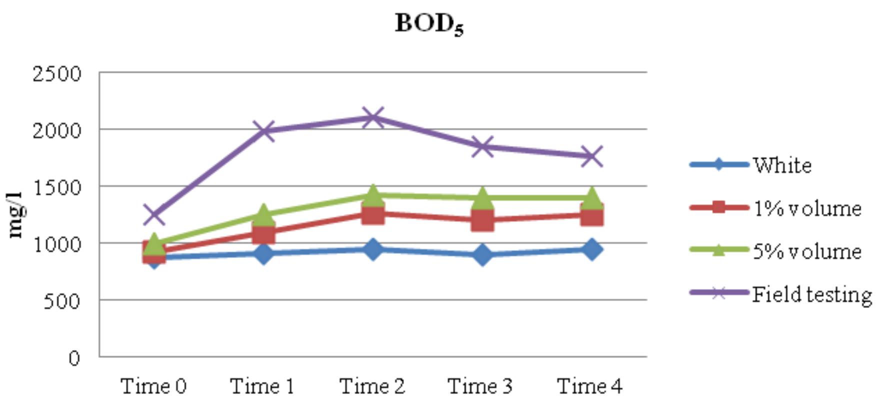

Fig. 6: Results of BOD_5 from laboratory tests and field testing.

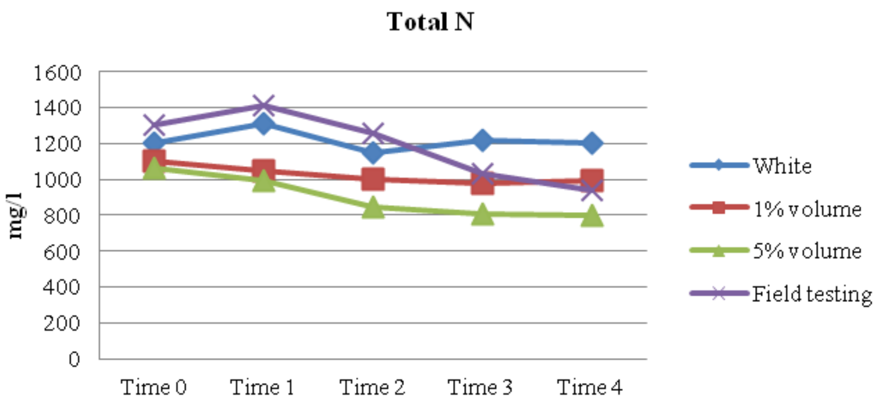

Fig. 7: Results of Total N from laboratory tests and field testing.

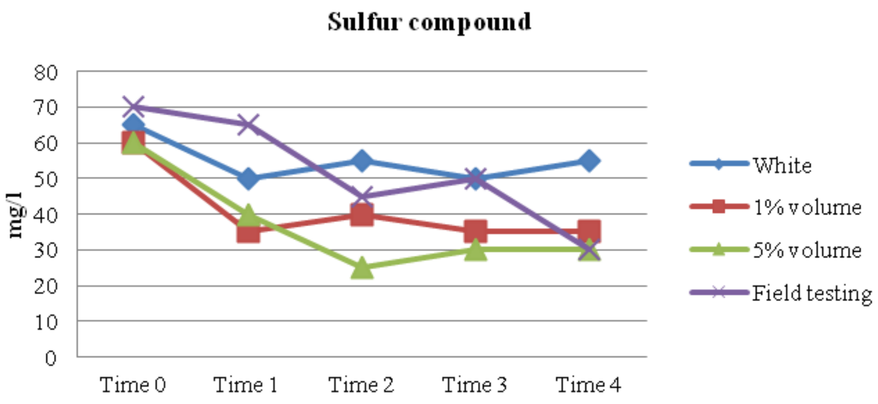

Fig. 8: Results of Sulfur compound from laboratory tests and field testing.

4. CONCLUSIONS

Starting from results just been reported it is possible to say that the biotic conditions put in place following the distribution of the test substrate above the substrate present in the biofilter, can significantly affect the density of microbial colonies present on the wood chips. It is possible to indicate the period of maximum effectiveness in the time interval between 15 and 45 times days of test 3 and 4. In order to assert hipotesys expressed before.

In support of the above argument is also useful to observe the evolution of the concentration of nitrogen compounds and sulfur. In both cases it is noted a significant reduction of both classes of pollutants monitored.

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First communication

ANCIENT ROADS IN SOUTHERN ITALY: AN HYPOTHESIS OF REQUALIFICATION FOR THE VALORIZATION OF THE RURAL LANDSCAPE

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Abstract. *The rural heritage of a specific area represents the form that man has been able to give to its surrounding landscape. Over the centuries, in many European rural areas, roads have lost their traditional design motivation. Their requalification, in the framework of a sustainable development of rural areas, can be an important way for the protection of the landscape. Through the provision of new alternative activities, compatible with the particular nature of the environment, new opportunities for a sustainable preservation of the environment are possible.*
The "Francigena Way" is a combination of arterial roads dating back to the Roman era. The "Herculia Way" is part of the "Francigena Way" that was built in southern Italy. The aim of this research is to study a possible requalification of a part of the Herculia Way. Some ancient paths, known as "tratturi" (sheep-tracks) and small royal tratturi, in some measure still existing, have been identified and located on historical maps. One of these paths has been chosen for the present analysis; different surveys have allowed us to identify some rural buildings along its route, with a significant architectonical, historical and landscape value. The hypothesis of a structural and functional recovery through their maintenance and restoration will help the sustainable protection and enhancement of the landscape.

Key words: *path valorization, Roman ways, rural landscape, agricultural buildings, sustainable development*

1. Introduction

The history of an area can be understood through a careful examination of the natural elements and architectural features which are found in it.

Extra-urban areas have always been environments where important forms of natural landscape can be found. These originate in the old coexistence of the natural environment with the presence of man. In many rural areas, across the centuries, roads and buildings have lost their original use due to major changes which occurred in the local countryside. In particular, during the second half of the last century, socio-economic changes have led, at a European level, to a progressive rural depopulation, promoting the centralization and industrialization of urban areas. The changes have also affected the rural landscape of southern Italy, where buildings and rural roads have always played a central role in the way of living mainly connected to the peasant and rural environment. At the local level, the population has inhabited these environments leading to the definition of specific cultural identity.

The combination of these factors, tangible and intangible, has helped these environments to obtain a characteristic of irreproducibility in other places: they identify the environment described in a unique way. The gradual state of deterioration of the landscape leads, over time, to the inexorable loss of valuable local and cultural identities linked to the nature of the territory. The neglected rural heritage is destined to disappear. The conservation of this precious natural resource aims to protect the local rural landscape. The area investigated is part of the broader Agri Valley, in the south of the Basilicata Region. It has several geological basins with tectonic - karsts springs, natural caves and sinkholes. The original landscape dates back to about 200 million years ago with the sedimentary formation of the first mountains. It is an area that, because of its particular orographic and soil fertility, presents beautiful natural landscapes. Its central geographical position in the region and the particular shape made of valleys and clear rounds between extremely pronounced mountain formations have made it, over time, a strategic internal junction for rapid road transport and a direct connection to the most important destinations near the sea.

The development of internal connections facilitated the defense of the territory by the local population and over the centuries, for various reasons, they have left important signs of their culture.

All this has led to the definition of special forms of rural architecture, archeology and religion in the area. These factors delineate rural landscape characteristics making its protection and preservation a priority. The buildings which are inserted in the rural countryside of the Basilicata Region demonstrate a harmonious blend of architecture and environment that has evolved across the centuries promoting the natural vocation of the local areas observed.

1.1. Valorization of the rural landscape

Among the rural buildings and the agricultural landscape there is a very delicate equilibrium. The role that rural buildings have historically played is closely connected with the surrounding environment [11]. Decision-making processes must ensure harmonious relations between environmental integrity and preservation of historic rural buildings, integrating what has been built in its landscape. In the last decade, throughout Europe, it was possible to observe some major changes in the relationship between buildings and their rural landscapes [10]. The programming of the European landscape policy has special building codes to protect local cultural identity and promote the quality of the landscape [3].

Guarantying the conservation of the rural heritage, which has been abandoned and destined to disappear through its conversion to new uses means protecting the local rural landscape with its tradition and its culture [8]. Reusing the elements of rural architecture abandoned to accommodate new alternative activities compatible with their characteristics represents an appropriate option for a long-term sustainable conservation as it provides a utility for owners ensures the proper maintenance of the properties and helps to protect the value of rural landscapes [4].

In the second half of the twentieth century, an increasing demand for goods and services in rural areas took place, such as recreation, consideration of the landscape, and diffusion of traditional and cultural tourism. The use and economic promotion of these resources offer a real opportunity for the diversification and improvement of local economies [15]. The promotion of the territories through tourism has long been considered a powerful tool for development able to stimulate the economic growth and increase investment and local employment [6]. The vernacular architecture of a given area is a symbol of identity, as well as rich ethnographic evidence on rural technologies and ways of life in rural areas [7]. It has been shown that, in some cases, tourism has resulted in greater protection and conservation of the environment [13]. Experts agree on integration and adequate environmental location, able to balance harmoniously rural buildings related to tourism within their landscape setting [14, 1]. The interventions carried out by humans often have heavily influenced the agricultural environment and the visual perception of the landscape [9, 12].

The Francigena Way is situated in southern Italy. It connects the center of Europe, with Rome, Jerusalem and Santiago de Compostela. It is the most important pilgrimage route dating back to medieval times. Herculia Way is also included in this Way. It breaks away from the Traiana Way in the north and runs towards the south in the center of the Basilicata Region until it gets to the ancient Town of Grumento, and then continues in the east towards the sea.

The aim of this study is to hypothesize a possible environmental regeneration and function of a stretch of the route of the Herculia Way found in the Basilicata Region in order to protect the identity of the local landscape for the future.

1.2. The Herculia Way

The Herculia Way connects the north to the south of the Basilicata Region. It was built during the age of the Roman Emperors, Diocletian and Maximian Herculius, from which it takes its name. The aim was to link the Town of Grumento with the "Appia Way" in the north, the "Popilia Way" and the Ionian Coast to the east. At that time it became the main road used by pilgrims travelling from Rome to Jerusalem. It was also used by merchants in transit through the region.

In the Middle Ages, the main axes of the road network of the Basilicata Region reproduced the ancient Roman paths connecting, as far as possible, all the territory of the old Basilicata Region. These were the Appia Way, the Capua-Reggio Way and the Herculia Way. This last ancient Way represented the most active arterial road that crossed the territory of the Region. It facilitated the transit of goods and armies towards the Ionian coast and the displacement of the pilgrims to different dioceses.

1.3. The road axis "Grumentum - Potentia - Venusia": the most important part of the Herculia Way

The existence of the Herculia Way dates back to the early Middle Ages. In fact, during this time the presence of minor roads appeared. It is a simple road network with only a few extending from it.

This system of internal and side roads was perceived by "Procopio" as two types. The most important type was the “publicae” roads: managed by the public authority that controlled them. They were used by armies, merchants and pilgrims. The second type of road included harsh winding paths, similar to mule tracks, as well as winding paths located along the ridge or crest. Little maintenance had been done to these roads generally known only to the local inhabitants [5]. The articulation of this minor road network occurred because of economic reasons as well as the emergence of new settlements. In this way, the roman concept of linear road was abandoned and a new concept of roads was now understood as the medieval road network (*strata, via, iter, itinerarium*) [2].

This road network was more articulated and was intended to serve different purposes. The Herculia Way was built considering strategic military targets. Therefore, it is a set of macro paths, connected to micro paths, built and developed to meet the needs of local residents. From the town of Grumentum it continues towards the ancient greek city of Heraclea, crossing south of the Agri Valley and linking the towns of Spinoso, San Martino d'Agri, Roccanova, Sant'Arcangelo and Tursi. An intermediate station should probably fall in the area of Sant’Arcangelo. This road is the route of the Herculia Way [2].

2. MATERIAL AND METHODS

Targeted inspections were conducted with the aim of analysing the significant elements of local rural architecture, capable of interpreting the history of the landscape and, therefore, the characteristic elements of rural heritage.

The rural buildings, identified along the road stretch investigated, were the subject of a photographic survey and a survey of their geographical coordinates in order to be able to assign the exact geographic position on georeferenced cartographic material. It has thus been possible to identify the traits of sheep tracks (Fig.1).

For the structures identified were compiled technical cards in situ. They were collected data and information on the buildings, about on their typology, historical use and form of possession, size, construction materials and current state of conservation of the buildings.

Interviews were carried out with the locals in order to get more information.

The purpose of this study was to analyse the rural buildings encountered along the route investigated. The most representative were identified in the present research. The prevalence of structures of different sizes and of a religious nature in the rural territory indicates a strong religious culture in the past. The presence of rural farms was not as frequent.

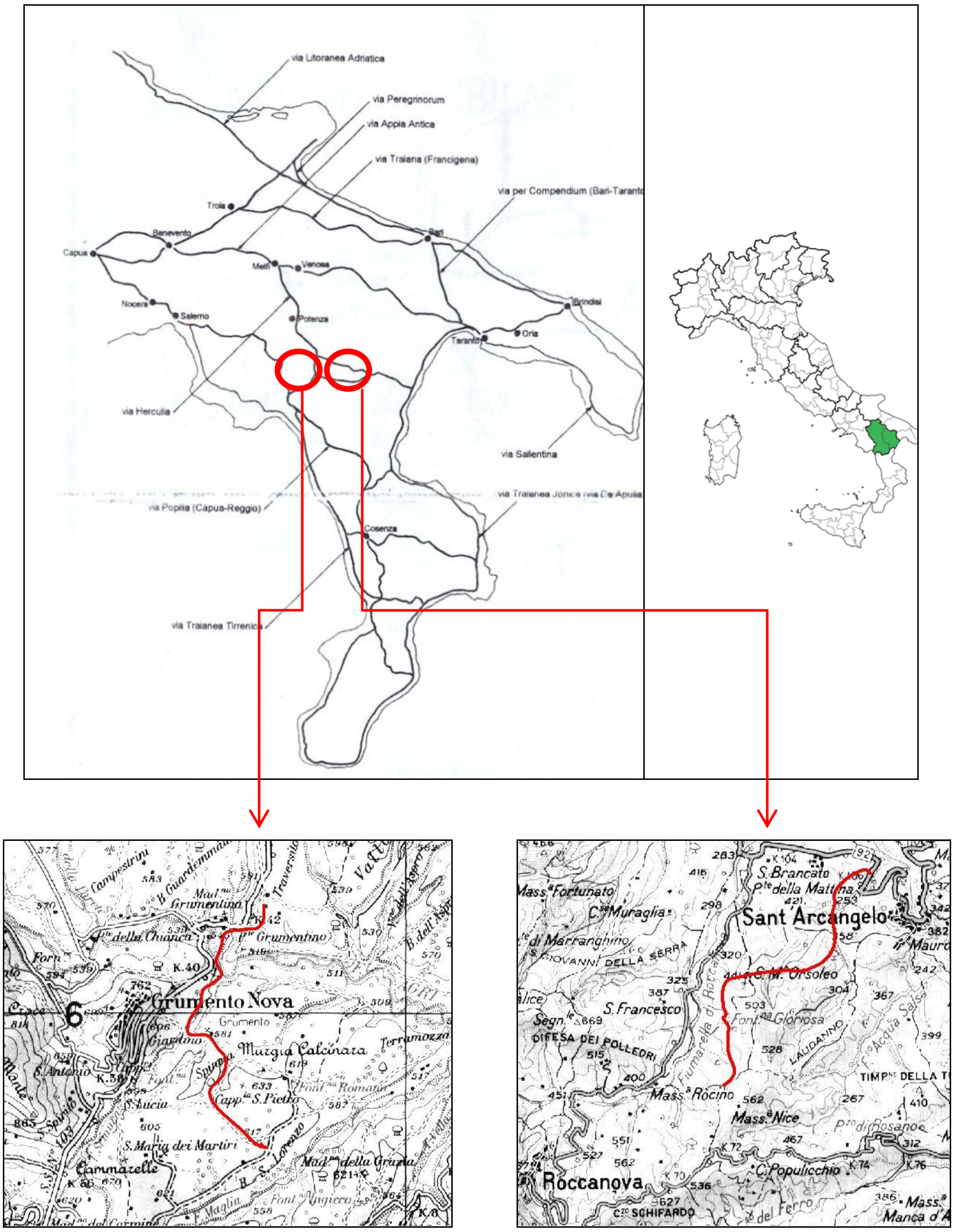

Fig. 1: Roman roads in the Middle Ages in the Basilicata Region
and sheep tracks identified.

3. Results and discussion

The buildings identified along the way have a strong historical value. In fact, it was possible to notice the presence of buildings of special architectural and landscape value (Fig. 2).

Fig. 2: Historic rural landscape located in the "Agri Valley" in the Basilicata Region.

The analysis of the buildings observed shows the presence of different typologies of rural structures in the territory located in the natural landscape. It concerns small and medium size buildings having had little maintenance or having been completely abandoned. However, in some cases, medium and large constructions have been well preserved. They are of a religious nature, such as churches and rural sanctuaries, which testify to the great importance that religious pilgrimages have had in the past (Fig. 3).

The second typology of buildings observed, in a smaller number of cases, concerned buildings of smaller size. These are small refuges, allocated in the area of the inner roads, once used by local farmers as auxiliary to the local agricultural activity carried out in the fields or as refuges for the animals raised for family consumption.

In some cases, fountains used in the past for local agricultural use or for the needs of travellers, traders and soldiers can be found near these structures.

Fig. 3: Rural religious building, located in the Agri Valley, in the Basilicata Region.

In all cases, the observed structures are made of poor materials, locally available, such as stones, clays and wood.

Rural buildings for agricultural purposes of a larger size have been observed only in a few cases. The presence of useful structures, used for the conservation or processing of agricultural products, such as small mills, was also important. A link between the identified structures and privately owned sheep-tracks has been observed in the natural landscape. The construction works and sheep tracks observed were analyzed by taking photographs and GPS coordinates. A concentration of buildings along rural roads that are related to roads of higher relevance was observed using the positioning of these pictures and the georeferenced cartographic material.

In this way, it was possible to identify the bundle of sheep tracks that converge to the Herculia Way, proving, within a small margin of error, its role in the Middle Ages as one of the most important road connections in southern Italy.

Currently, a growing interest in rediscovering places of cultural and natural interest is occurring. Therefore, the possibility of a recovery of the old rural routes linked to local cultural traditions is essential, in order, to raise the awareness of landscape resources which are poorly understood.

The hypothesis of a structural restoration of the observed paths can be useful for new forms of alternative economic activities compatible with the nature of the place, with paths accessible on foot or on horseback.

Fig. 4: Tratturi (sheep-tracks) along the Herculia Way.

These activities could use the old abandoned rural structures that were used by pilgrims and horses. Similarly, the presence of fountains along the roads could be useful. In this way, the natural equilibrium of the environment would remain unchanged and, especially, the natural resources would be preserved and respected. The preservation of the landscape and the sense of place in the long term could be achieved by increasing the competitiveness and environmental sustainability in accordance with the international lines of economic and environmental development.

4. Conclusions

The stretch of the Herculia Way that was analyzed provides many examples of rural architecture in the countryside which appears as unique within the natural environmental context of the area. These factors constitute the rural landscape, rich in traditions and cultures, belonging to the history of the place. The analysis of the elements observed along the stretch of the campaign investigated, showed the existence of a rural heritage worthy of enhancement and of architectural and international interest. To do this, it is necessary to continue the analysis of the elements of the rural landscape and, above all the examination of existing buildings is important. The protection and enhancement of these resources is necessary to preserve them, making them accessible to younger generations, along with the agricultural landscape in which they are inserted and in which they are an integral and essential part.

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Scientific review paper

ENERGY IN AGRICULTURE: CONSUMPTION VS. PRODUCTION

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Abstract. *Agricultural sector is considered as a non major energy consuming sector. However, the energy consumed in agriculture considerably affects the cost of the agricultural products and as a consequence the agricultural market. For this reason, the use of alternative energy sources in agriculture is of importance to keep the agricultural product prices in low level. On the other hand, agriculture appears to be an important energy producing sector, taking into account that biomass either in the form of energy cultures or agricultural waste and residues are also agricultural products or byproducts. Under these circumstances and taking into consideration the recent energy crises, EU encourages the biomass energy production, which can replace considerable amounts of polluting conventional fuels.*

Key words: *agriculture, renewable energy, energy consumption, energy production, biomass*

1. ALTERNATIVE ENERGY SOURCES

The development in today's technological society is based entirely on the exploitation of exceptionally large quantities of energy. Energy exploitation covers both the production and the rational use of energy: that is, the discovery of new energy resources (conventional or renewable) and the search for ways to use these resources more efficiently.

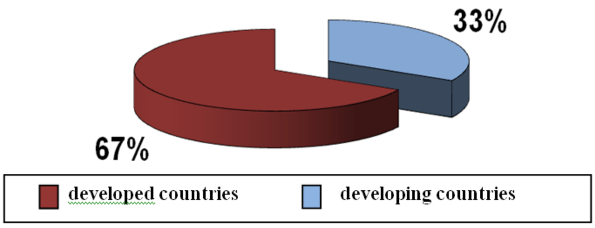

Fig. 1: World energy market.

Conventional fuels currently constitute the principal source of energy in both “developed”, or “industrial”, and developing countries (Fig. 1, Fig. 2).

These fuels, however, which are chiefly found in the deeper in the earth, are unevenly distributed around this planet. These results in economic and political disputes between countries, rooted in the energy policies they pursue. A recent example of this is seen in the consequent energy crises from the ‘70s till nowadays, which had such an impact on the world economy.

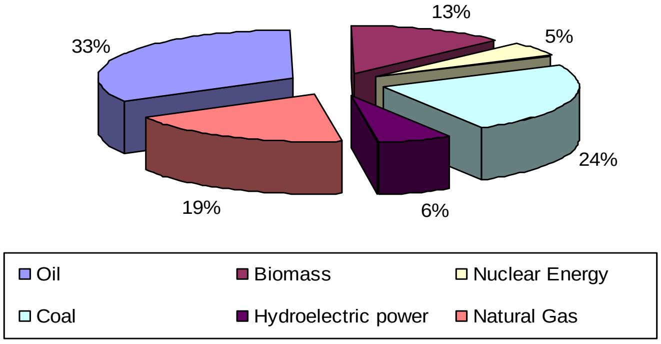

Fig. 2: Energy sources distribution within the world energy product.

Economic development, moreover, goes hand in hand with energy consumption: this is reflected in the close correlation between Gross National Product and per capita energy consumption [6] graphically displayed in Fig. 3. For the aforementioned reasons as well as in order to make some degree of energy self-sufficiency possible, particularly in countries that are not major oil producers and those with high levels of energy consumption, great emphasis has been put on research into the exploitation and use of inexpensive and readily available energy resources, such as the renewable energy sources.

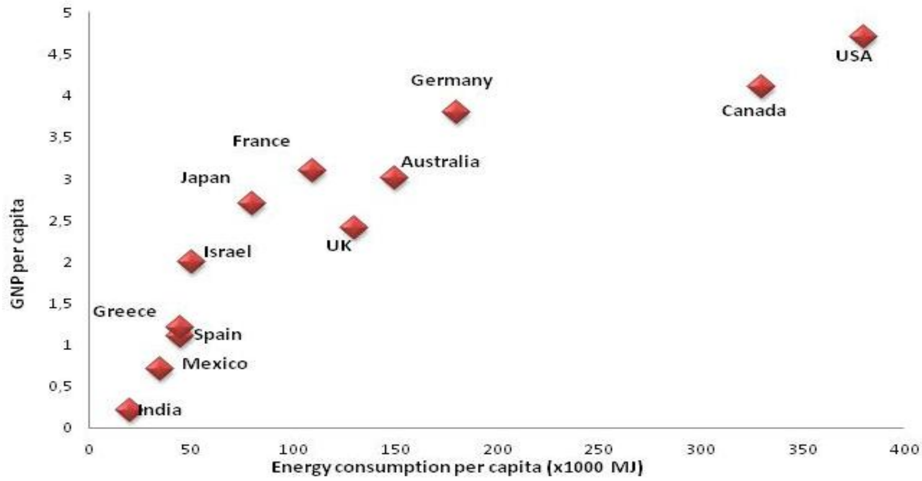

Fig. 3: Energy consumption per capita [5].

Looked at this way, the sun is the basic source of most of the renewable forms of energy that are available on this planet. Meeting energy needs through solar power is done both [4]; directly (heat) and indirectly. Solar energy is tapped indirectly through: a) the movement of air masses, which is due to temperature differences between two points of the atmosphere creating winds (wind power); b) the evaporation of water from areas of low atmospheric pressure on the earth's surface and its subsequent re-condensation over areas of higher pressure, which creates exploitable precipitation, and c) photosynthesis, which is the solar assisted photochemical conversion of carbon dioxide and water to biomass with subsequent release of oxygen, which returns to the atmosphere. Biomass is one of commonest and most traditionally exploited energy products.

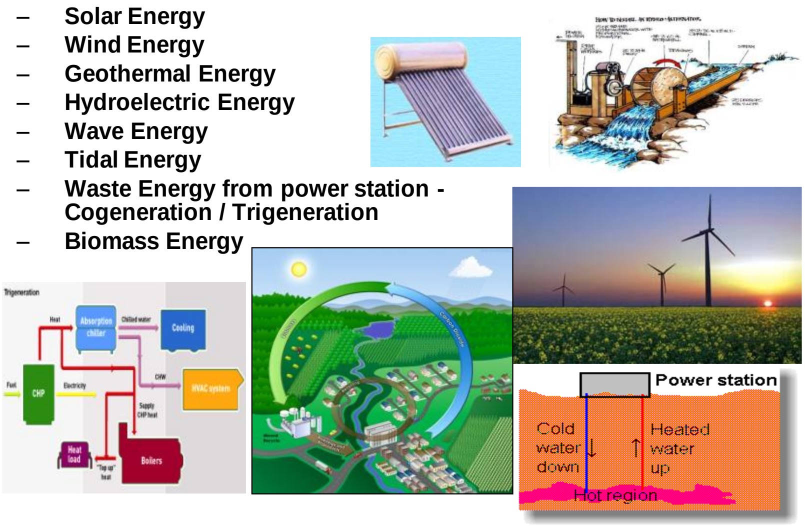

Fig. 4: Alternative Energy Sources.

Other interesting renewable energy sources are, also, the geothermal energy, that is owed in the heat of subsoil, as well as the tidal and wave energy. Finally, appreciable is also the exploitation of rejected energy from energy consuming installation, such as the power stations as an alternative energy source. From all the aforementioned alternative and renewable energy sources (Fig 4), the solar energy, the geothermal energy, the biomass energy, and the waste energy are considered of a special interest for exploitation by the agricultural sector while the use of the wind energy and the hydropower from small waterfalls are is appearing to decline, nowadays.

2. THE AGRICULTURE AS AN ENERGY CONSUMER

Agriculture, in world level, is not particularly considered as a major energy consuming sector for productive activities. However, it is of particular interest the investigation of the known relations between the production of agricultural products, the labor productivity and the energy demand for the production. This investigation was observed distinctive differences in the used energy per agricultural worker between the developed and the developing countries. As an example, the comparison between Northern America and Africa for the direct consumption of energy per agricultural worker was found to be 10.72 kg OE (Oil Equivalent) per worker and 6 kg OE per worker, respectively [4]. Nevertheless, the relation between the increase of the agricultural production output and the corresponding increase of energy consumption [2] or in other words the elasticity of energy in a percentage basis appeared to be better in the developing countries than in the developed countries, confirming, thereafter, the law of the not proportional output.

3. Energy in European agriculture

The different energy sources are grouped into categories as follows:
- Solid fuels (coal, lignite, briquettes, etc.)
- Liquid fuels (diesel, light and heavy oil)
- Gas fuels (natural gas, LPG)
- Electricity (1 kWh = 3.6 MJ, or 1GWh = 3.6 TJ = 86 TOE)
- Commercial energy (steam, hot water)
- Renewable energies (firewood, biomass residues, biogas, geothermal energy, solar or wind energy, hydro power).

Total energy consumption is directly connected with the intensity, structure and technological level of agricultural production, as well as with the climatic conditions prevailing in each region.

The share of energy that is consumed by the primary agricultural sector amounts 6.5% of the globally spent energy. In the European Union (1), from the total energy consumed an amount of 68% concerns the consumption of liquid fuels (Fig. 5). This is used mainly, for the agricultural machinery operation and the agricultural products transportation (60%) as well as for the drying of agricultural products and the heating of greenhouses and stables (40%).

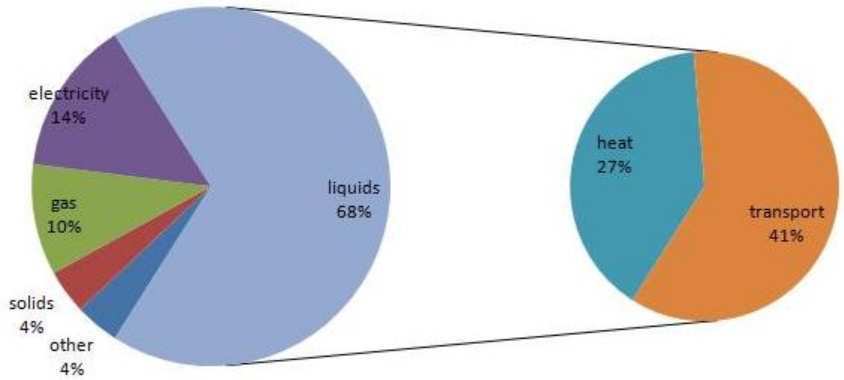

Fig. 5: Energy sources used in agriculture [5].

Proportions of other energy sources used in agriculture are:
- electric energy 14%

- solid fuels 4%
- gas fuels 10%
- other energy sources 4%

The total efficiency of the energy used in the agricultural sector can be expressed as the ratio of total energy consumption to the value of the gross agricultural product. In Europe the overall average is 191 kg OE/ 1000€, while the figures for different regions are [5]:

- Western Europe: 212 kg OE/1000 €
- Northern Europe: 156 kg OE/1000 €
- Eastern Europe: 250 kg OE/1000 €
- Southern Europe: 170 kg OE/1000 €

4. THE AGRICULTURE AS ENERGY PRODUCER

In 2007, the European Committee [7] in the frames of its energy policy placed for concretization from the member states, up to 2020, the following objectives:

- The reduction of greenhouse gas emissions of at least to 20%, compared to that of 1990;
- The increase of energy output at 20%;
- The increase the exploitation of renewable energy to 20%;
- The increase the use of biofuel percentage for transports to 10% of the total fuels.

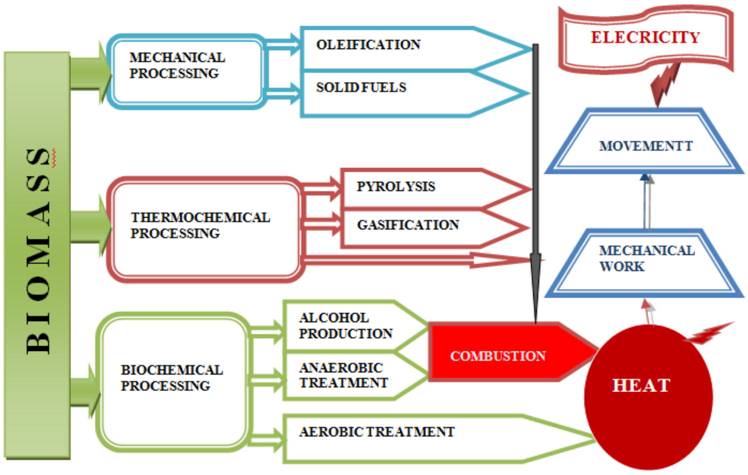

Fig. 6: Schematic diagram of energy utilisation methods of biomass.

The saving of energy in the rural sector, even if it is considered very important for the configuration of low cost of production of agricultural products, does not participate substantially in the achievement of this objectives, since agriculture is considered as a minor energy consumer.

On the contrary, the production of energy products that are based on biomass (Fig. 6), renders the agricultural sector as an important factor for the reduction of pollutant conventional fuels and the saving of energy [4]. The rational exploitation of the rural wastes, the agroindustrial sewages and plant residues for energy production as well as the production of raw material, as by-products, from energy cultures constitute today particularly profitable agricultural investments.

The energy products that emanate from biomass may have the form of solid (timber, charcoal), liquid (alcohols, biodiesel) and gas (methane, hydrogen) fuels. From them, the liquid and the gas fuels can substitute conventional fuels for transport.

In the EU-27, the contribution of biomass to the primary energy production was about 68% of total of renewable energy produced in 2010 [1]. From the total of this biomass, 87% constituted solid fuels, 7.2% liquid biofuels and 5.8% biogas.

Biomass electricity in the EU increased from 69 TWh in 2005 to 123 TWh in 2010 and is expected to reach 232 TWh in 2020. The contribution to electricity made by bioenergy will reach 19 % of RES electricity in 2020, according to the aggregated data of the NREAPs.

Remarkable is, also, the exploitation of biomass with bio-refinery systems (Fig. 7) for the production of second generation biofuels in parallel with the co-production of other useful [3].

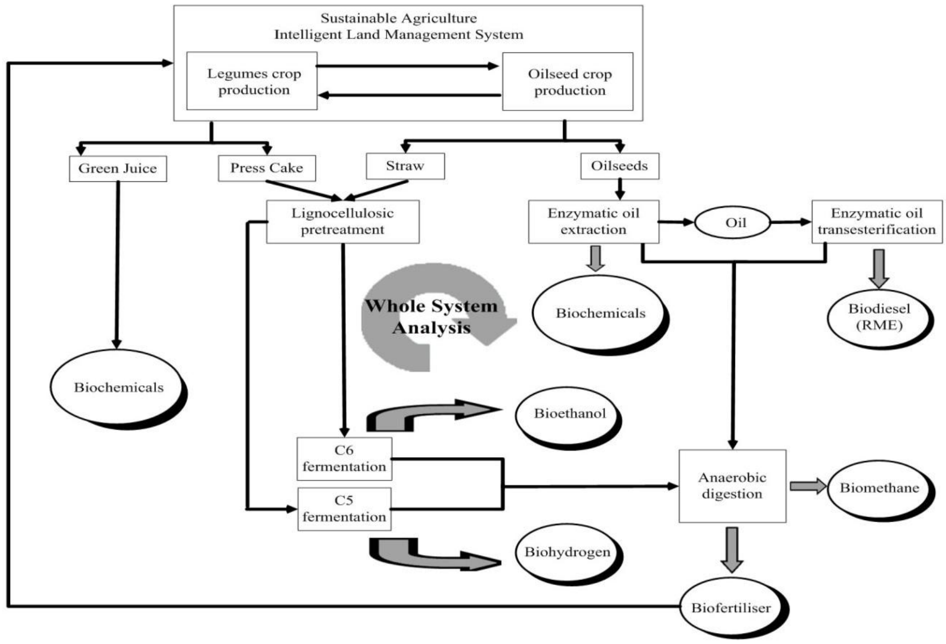

Fig. 7 Bio-refinery flow chart

Finally, the exploitation of bare and rocky lands as well as of the agricultural buildinroofs, such as the rural sheds and livestock buildings with the installation of PV panels (0.125kW - 0.8 kW m^{-2}) constitute modern alternative activities of the agricultural sector to be aligned with the direction of the aforementioned objectives that have been put by the EU.

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Scientific review paper

THE CURRENT STATE OF RENEWABLE ENERGY SOURCES OF ELECTRICITY IN SERBIA

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Abstract. *An analysis of the development of renewable energy sources (RES) and their influence on the development of an improved concept of electric power system having distributed electricity production in Serbia is presented. The state and prospects of the future development of renewable energy in Serbia are presented in detail. The impressive development of renewable energy sources in Europe and worldwide which occurred while doing this study has been taken into account. Annual gross energy consuption in Serbia is about 17 Mtoe and near 6% is produced by renewable energy sources, namely, by hydropower plants. A review of the RES potential and a brief analysis of the implications of ther use at the cost of electricity production in Serbia is included.*

Key words: *renewable energy sources (RES), potential, electric power system, distributed electricity production.*

1. INTRODUCTION

From the point of view of renewable energy sources (RES) available in the Republic of Serbia, by applying presently known technologies, one can define the following classification which takes into account the origin of any energy source [1]:

a. Direct solar irradiation energy;
b. Biomass energy;
c. Hydro energy;
d. Wind energy;
e. Geothermal energy.

In the course of RES analysis, especially for electricity production, two exceptionally significant potentials which can contribute to a higher productivity level of electrical energy within a system can be defined. These are:

1. *Rationalization of energy use* – energy efficiency;

2. *Potential of replacement of one type of energizer by another*, i.e. replacement of an electricity consumer by a non-electricity consumer.

Taking into account the overall energy potentials and needs, the potential of rational use of electrical energy, including energizer substitution, is often more significant and justifiable for the purpose of relieving production capacity of the electric power system (EPS) than the total potential of electricity production from RES.

The potential defined for an energy source can be classified in three subsets [2]:

1. *Theoretical potential* – Total potential of the energy source calculated theoretically on the basis of natural resources of a region. It is dependent upon natural resources therefore it is almost invariable, i.e. varies very slowly and in a known way.

2. *Technically achievable potential* – Total potential which could be converted into a useful form of energy involving a positive material/energy from the technological point of view. It is relatively slowly variable and is primarily dependent upon available technologies applicable in the process of exploitation of a RES.

3. *Economically profitable potential* – Total potential whose exploitation, under given economical conditions, can be financially justified. A potential considered that way is dependent upon many factors, predominantly upon the current state at the market of energizers, therefore its variation is very fast.

Analyses of RES usually deal with technical potentials taking into account, to some extent, the theoretical and economic aspects of RES - the approach adopted in the present work.

2. MATERIAL AND METHODS

Total annual consumption of primary energy in Serbia amounts to 17 Mtoe. End-use energy consumption is about 8.2 Mtoe, the dependence upon imports being 37%. The electrical energy consumption in Serbia is about 3 Mtoe (35 TWh). The portion of RES participating in the electrical energy production, more precisely the potential of hydro electric plants, amounts to 34% (the portion of RES participating in the primary energy production is about 6%), which makes a significant percentage compared to a large majority of highly developed countries of Europe [3]. It should be emphasized that the use of biomass, primarily for heating, has not been statistically processed, but it is estimated that approximately 25% of households in Serbia use biomass for heating [4].

The official estimate is that in Serbia total potential of RES is about 4.3 Mtoe, which represents about 25% of the total primary energy consumption (PEC). The potentials of individual resources amount to: Solar radiation (SR) – 0.6 Mtoe; Biomass (BM) – 2.7 Mtoe; Unused hydro potential (HE) – 0.6 Mtoe; Wind energy (WE) – 0.2 Mtoe; Geothermal sources (GTS) – 0.2 Mtoe [5].

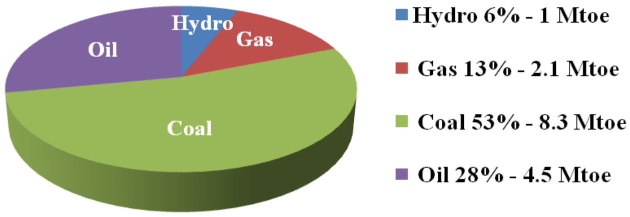


Fig. 1: Participation of individual energizers in the total primary energy consumption in Serbia *(%, Mtoe)*.

It is important to note that certain potentials, such as solar potential for electrical energy production or geothermal energy potential, have capacities which theoretically, but also technically, can meet the total energy demands. Since, from the current economical point of view, such assumptions exceed many times, even for very optimistic, estimates of the developments of energy sectors anywhere in the world, these alternatives have not been analyzed in detail, therefore they are not considered in the present work.

Studies made during the last ten years point at the significant potential of rationalization of use of electrical energy – energy efficiency (EE), estimated at 40% of PEC, thus it is often said that our most significant RES indeed is rationalization of energy consumption [6].

On the basis of the plan of the Ministry of Energy, Development and Environmental protection of the Republic of Serbia, up to the year 2020 the RES-based power plants totaling 1000 MW should be built, based on wind-, hydro-, and biomass potentials [4].

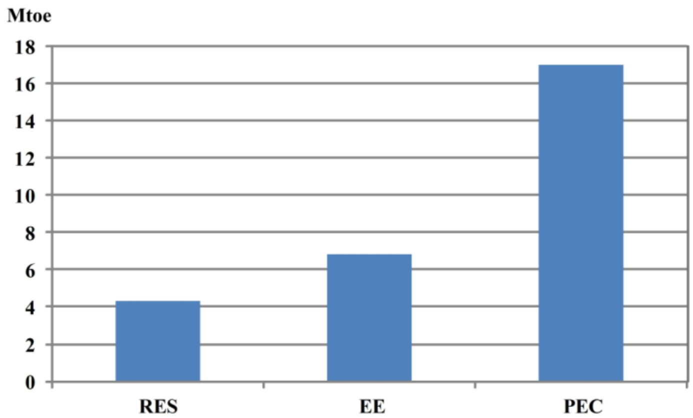


Fig. 2: Potentials of individual RES compared to the primary energy consumption (PEC) and the potential of rationalization of energy use (EE), expressed in Mtoe.

2.1. Solar radiation energy

Solar energy can be used directly for heating of water or production of electrical energy. Room heating is also possible, but the general problem with solar energy is that it is the least available when it is most needed and vice versa, therefore the systems for room heating are usually very unprofitable and will not be considered in this work.

Compared to other countries, Serbia is positioned in the region of average irradiation. It has been measured that the theoretical potential, i.e. energy irradiated by the Sun on the horizontal surface, at annual level, is about 1.3 MWh m^{-2}, or about 0.1 toe m^{-2} [1].

2.1.1 Systems for water heating by solar energy

It has been estimated that the potential of solar energy for water heating in Serbia is 0.6 Mtoe. By taking into account that the pay off period for this type of investment is 3 to 7 years, that most of the heated water in households is prepared in electric storage heaters, as well as that an exceptionally high percentage of the produced electrical energy is spent for this purpose, it is concluded that these systems are of an exceptional importance for relieving electric power system and that they should be applied as much as possible.

2.1.2 Systems for production of electrical energy from solar radiation

Two basic technologies for production of electrical energy from solar radiation prevail in the world today. These are: photovoltaic conversion (PV) and thermo-solar power plants (TSPP). Since TSPP need very large surfaces to be occupied, the PV technology is preferable for Serbia. Even though they are considered to be one of the most costly type of production of electrical energy, the development of PV electric power plants is blooming throughout the world over the past several years, the annual growth of installed capacities reaching 130%. A total of 100 GW of photovoltaic plants has been installed throughout the world by the middle of 2013 [3].

Prices of PV panels are dropping continually, thus the cost of investment in a PV power plant is already below 2 euro per installed watt. At the geographic position of Serbia, usability of an installed PV capacity at annual level is about 15%. The subventioned cost of electrical energy from solar power plants is 23 eurocent per kWh. The status of a privileged producer of PV electrical energy has been declared for the total of 5 MW of installed capacity by the end of 2012 [1].

Theoretical potential, technically achievable today, for production of electrical energy from solar radiation, together with energy accumulation, could completely cover the needs for electrical energy of Serbia. Under existing market conditions, this consideration can not be justified economically for many reasons, therefore it has not been taken into account by the official estimates and short term development plans. However, a potential of these proportions should certainly not be marginalized nor excluded from research programs, but it is required to work continually on technical development of solar electric power plants in order to make them approach the limit of economic acceptability.

2.1.3. First solar electric power plants in the electric power system of Serbia

The first electric power plants connected to the electric power system of Serbia have been realized through the project of the Agency for Energy Efficiency called: *Development of capacities for use and promotion of solar energy in Serbia*. The first connected is the plant in Varvarin (April 2011.), then in Kula (May 2011.), and finally in Belgrade (July 2011.), all three on the roofs of secondary schools. Rated power of each of them is 5 kW, and in addition to the demonstration-investigation purposes, the most important function of them is educational. The expected annual production of electrical energy from all three plants is about 17 MWh. Building of another several solar electric power plants of increased power is planned to be completed by 2015.

2.2. Biomass

The potential of biomass has been officially estimated as the most significant RES of Serbia, amounting approximately 2.7 Mtoe. Participation of biomass from agricultural production is 60%, while contribution of forest biomass is 40%. Unfortunately, there is no official statistical monitoring of application of this resource, but, according to the Action Plan for Biomass, significant developments are expected in this area.

From the technical point of view, the spectrum of possible biomass applications is very wide and it is often difficult to establish unique standards in all areas of its exploitation. According to the mode of application, biomass can be classified in the following way:

1. Solid biomass (logs, chips, hay, cornstalks, seeds, shells, briquettes, pellets, etc.): suitable primarily for production of thermal energy, to a lesser extent for production of electrical energy.
2. Biofuels (biodiesel or bioethanol): used primarily for traffic needs.
3. Biogas: can be used for production of both, electrical and thermal energies.

The rule which can be applied to all energy sources - the less processing and shorter times of transportation/storage give a more profitable usage - is best demonstrated by biomass which can be transformed in a wide variety of ways, but it is always most profitable to use it on the site with the minimum processing.

2.2.1. Solid biomass

Solid biomass covers: firewood, remains from wood processing industry, remains from agricultural production, straw, cornstalks, seedcases, shells, seeds, plants cultivated for energy production, briquettes, pellets, etc. In majority of cases, under applicable market conditions, solid biomass is concurrent to other fuels when production of thermal energy is in question. For this reason the use of biomass in Serbia is quite widespread. It is estimated that about 400.000 households use biomass for heating, which corresponds to the energy value of 0.3 Mtoe [1].

Unfortunately, traditional exploitation of biomass relies on use of low efficiency stoves, which could be considerably improved. Briquettes and pellets production has recently experienced real blooming since it turned out that this is a very profitable business, thus the existing capacities in Serbia in this area are almost fully engaged. In about ten factories in Serbia the remains of industrially processed agricultural biomass are very successfully used in the production of energy required by the industrial process itself. In all these cases this investment turned out to be useful in many ways and it pays off quickly.

In Serbia, currently there are no power plants based on biomass connected to the electric power system. The subventioned price of electrical energy from power plants based on biomass is from 11.4 up to 13.6 eurocent per kWh [2]. Nevertheless, from the overall point of view of energy generation, the most significant is the possibility of a wider and more efficient use of biomass for production of thermal energy.

2.2.2. Biofuels

The concept of biofuel implies, first of all, biodiesel and bioethanol. The official estimate of the potential for production of biofuels in Serbia is about 0.2 Mtoe. The already existing facilities are capable of production about 0.1 Mtoe of biodiesel annually, but owing to non-profitability of this production they do not operate [2]. For bioethanol production there are more than ten completely different technologies. In majority of cases this fuel is a product of chemical industry. For this reason a unique optimal technology has not been singled out, but from case to case bioethanol production is adjusted to the primary technological system of the existing industry.

The use of biofuels is not very significant for electrical energy generation, even in the sense of fuel replacement. Its primary use is for traffic purposes.

2.2.3. Biogas

Biogas is formed by anaerobic digestion (decomposition in the absence of air) of organic materials. Practically, complete biomass (of vegetable or animal origin) can be used for its production. The main bearer of biogas energy potential is methane which prevails in the obtained biogas mixture, from 50% to 75% of the content [2]. Depending upon the mode (place) of production, there are: agricultural, industrial, trash pile, sewage, etc. biogas facilities.

Motivation for biogas production in developed countries most often is not for energy production purpose, but owing to the stringent ecologic standards forbidding release (outpouring) of bio-degradable material in watercourses. The subventioned prices for producers of electrical energy from biogas, applicable in Serbia are from 12 to 16 eurocent per kWh, i.e. 6.8 eurocent per kWh from electric power plants run by biogas from trash pile or the gas obtained from waste water processing facilities.

The Action Plan sets the target that by 2013. amount of 10.660 toe of electrical energy from biogas is obtained. The success of this plan will depend primarily on attractiveness of the offered subventioned prices.

2.3. Hydro electric power plants

From the RES electrical energy production point of view, hydro electric power plants are the most significant potential of Serbia.

According to the Cadastre of small hydro electric power plants (SHEPP) made in the eighties, it is estimated that in Serbia there are 870 suitable locations for building low power hydro electric plants (up to 10 MW), producing annually about 0.15 Mtoe of electrical energy. Potential of large hydro electric power plants (LHEPP, over 10 MW) has been estimated at 0.45 Mtoe [1]. However, owing to the unplanned constructions of infrastructural facilities, application of watercourses for other purposes (industry, waterworks, irrigation, etc.), as well as changes in hydrologic situation caused by deforestation and climatic changes, the latest investigations show that the number of available locations, therefore the available capacity, is far below the earlier estimate. More precise data are not available therefore the above listed data remain official.

Since introduction of the subventioned prices for production of electrical energy by SHEPP, interest of investors for SHEPP has been running very high. In addition to the existing small hydro electric power plants owned by EPS of Serbia, about 50 units, about

10 of them operational, hundreds of investors inquired at power distribution enterprises and local authorities about building SHEPP, several new SHEPPs already operational.

The subventioned price of electrical energy from SHEPP, depending upon the rated power and existing infrastructure, is from 5.9 to 9.7 eurocent per kWh. The investment costs are considerably dependent on the situation at the site and on installed power. This vale runs from 1.5 to 3 euro per installed watt, while the availability of an installed capacity (determined by the available flow and operational interruptions) is most often from 50% to 90%. Energetic licenses for building SHEPP at 317 locations have been issued in 17 boroughs and cities by the beginning of 2013. The estimated total value of investments amounts 500 million euro, most of it will be in underdeveloped boroughs [4].

2.4. Wind energy

The estimated potential of wind energy for production of electrical energy is about 0.2 Mtoe. The areas of high winds are Southern Banat, Danube valley, eastern parts of Serbia, as well as almost all mounting tops and passes allover Serbia. For a precise determination of sites suitable for building farms of wind electric power plants, it is required to perform measurements by professional equipment mounted on meteorological poles of a height reaching the one where the axes of wind turbines will be positioned (up to 120 m). These measurements should last at least for one full year, more desirable are 2 or 3 year periods. The results obtained by these measurements have to be extrapolated with the historical measurements made at the nearest meteorological stations in order "iron out" variations of the measured potential energy from year to year for as long period as possible [1].

However, in addition to a high average wind speed at annual level (from 5 to 8 m s^{-1}), for a location to be suitable for building a wind farms for electricity production, it is required that other necessary conditions are met:

a. The ecological and social standards should not be impaired;
b. The selected locations should have sufficient winds;
c. The corresponding electric distribution network for acceptance of the produced energy should be available together with a road infrastructure;
d. Building a farm of wind electric power plants at a selected site should be economically justifiable.

The fist 1.3 MW wind electric power plant has been connected to the EPS of Serbia in April 2011, at Tutin, the small town in western Serbia. Also, the first 100 MW wind farm will be built by the end of 2014 in Plandiste (the South Banat, District of Serbia).

Production of electrical energy by wind is relatively expensive. The subventioned price of electrical energy from wind electric power stations is 23 eurocent per kWh and, in addition, the limit for granting the status of a subventioned producer of electrical energy total of 400 MW of installed power was applicable until the end of 2012. The investment costs are about 1.5 euro per installed watt and suitable locations have the availability of installed capacity over 25%. The estimated potential of wind energy of Serbia can be considered satisfactory, taking into account the fact that EPS of Serbia cannot accept in a stable way more than 30% of energy participated by wind electric power plants, owing to the stochastic character of the production of wind electrical energy [1]. It is expected that several farms of wind power plants of typical power 10-100 MW will be built in Serbia by the end of 2020 [4].

2.5. Geothermal energy

Serbia is geographically positioned in a region of very favorable geothermal potential (thermal flux over considerable portion of the territory > 60 mW m^{-2}). Potential of the existing geothermal sources (drill holes, mainly owned by The Oil Industry of the Republic of Serbia) is about 0.2 Mtoe (without use of thermal pumps). Even though some of them are very lavish, temperature of majority of the sources is below 80^{o}C, i.e. unsuitable for production of electrical energy. Practically, only the source in Vranjska banja is of the adequate capacity for building a geothermal electric power plant [1].

Current use of geothermal energy in Serbia is way below real possibilities. Most often it is used for balneological purposes, but even there considerable improvements are possible. Also, there are about ten examples of use of geothermal energy by private investors.

The subventioned price of electrical energy from geothermal electric power plants is 7.5 eurocent per kWh. Depending upon the capacity and characteristics of the source, the investment costs in a geothermal electric power plant are 5 to 15 euro per installed watt for an already existing source, but the average annual availability of installed capacities usually is not below 90% [1].

However, exceptionally significant is the possibility of substitution of energizers by using geothermal pumps and geothermal probes for air conditioning purposes, especially with the aim of relieving EPS. Usage of geothermal pumps is already economically justifiable and investments to such systems pay off within the period of 3 to 10 years. Having in mind that by using geothermal pumps complete needs of Serbia for air conditioning purposes can be covered, this potential is of a very high significance.

3. RESULTS AND DISCUSSION

3.1. Investments in RES in Serbia

As regards investments in RES, several important questions are posed:

Do we obtain free energy from RES? Who is investing, who makes profit, and who is losing? Do we propel home economy and open new opportunities? Are we more energy independent and safer?

Energy, particularly electrical, obtained from renewable sources is not free. On the contrary, its transformation is often considerably more expensive than energy from coal, gas, or oil. However, one has to work on further improvement and gradual transition to RES, not for ecological reasons only, but also because of the fact that the conventional (not renewable) energy sources are finite and further growth of prices of energizers in the subsequent decades should be expected.

What is the investment cost in a RES for production of electrical energy, i.e. how much it affects its price, is shown by the following example [5].

A. Starting assumptions:

Production of electrical energy in Serbia:	E = 35 TWh $year^{-1}$
Desired growth of RES participation:	dE = 1% E = 350 GWh $year^{-1}$
Initial price of kWh:	P_o = 5/100 EUR kWh^{-1}

B. Variable parameter:

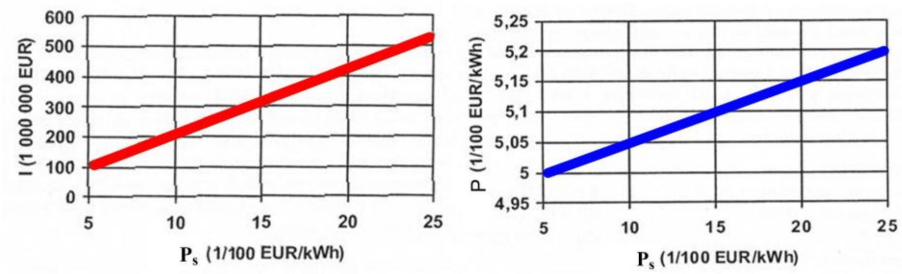
Subventioned price of kWh:	P_s = 5-25 /100 EUR kWh^{-1}

C. Calculated values:

Value of investment for pay off period 6 years: I = [1 000 000 EUR]
New price of kWh: P = [1 100 EUR^{-1} kWh^{-1}]

In the case of a simple investment return within the period of 6 years, it is necessary to invest:

$$I = 6 \text{ year} \cdot dE \cdot P_s \tag{1}$$



(a) (b)

Fig. 3: (a) Value of an investment which pays off within 6 years by simple investment return (1 000 000 EUR) as function of the subventioned price (1/100 EUR kWh^{-1})
(b) Value of the new price of electrical energy (1/100 EUR kWh^{-1}) as function of the subventioned price (1/100 EUR kWh^{-1}).

New price of electrical energy, after the increase of the participation of RES in production of electrical energy by 1%, will be:

$$P = (P_o + 0.01 \cdot P_s)/1.01 \tag{2}$$

Practically, the money paid by the citizens to cover the subventioned price of electrical energy goes to investors. Furthermore, it is distributed among investor's creditors, equipment manufacturers, and workers. In this process, reliability of a continual supply of electrical energy (energy safety) and technological dependence are in investor's hands.

4. CONCLUSIONS

The potential of RES in Serbia, from the theoretical and technical points of view, could completely meet the energy requirements of Serbia. Their application at present usually cannot be economically justified. On the contrary, an elemental transition to RES, accompanied by maximum subventioning measures would lead to a drastic jump of prices at the energy market, particularly at the electrical energy market.

In addition, relying on foreign investors exclusively, without developing home economy, education, and home entrepreneur (investor) initiative, could lead to the draining considerable means from the country, technical lag, excessive borrowing and, as a consequence, total destruction of many of the elements of the social system.

Through an initiative for a wider use of RES, the following should be achieved:

1. Clear definition of investments in the energy sector of Serbia in the future energy strategy, which implies the necessary stimulant measures, transparency, and efficient legislation;
2. A rational use of the existing and new power systems;
3. Enforcing home investments in RES, primarily in small power systems;
4. Investing in education and development of home technologies, adjusted to our own needs;
5. An elemental and unconditional transition to RES accompanied by excessively high subventions is avoided, but acting is according to a plan and in accordance with overall national interests and capabilities;
6. An ambient of entrepreneurship ready to appear at other markets on the basis of the acquired knowledge, developed products, and home investments is created.

In addition to the presented calculation, the experience of a large number of developed countries, holding currently world leading positions in the use of RES, also leads to these conclusions.

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First communication

ENERGY EFFICIENCY IN AGRICULTURE – OPPORTUNITIES, CONSTRAINTS AND RESEARCH NEEDS

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Abstract. *Agriculture as a primary industry relies on energy use to a great extent. With the depletion of fossil resources, increased energy prices will have a dramatic effect on the competitiveness of agricultural production systems and energy efficiency will have a great impact on the comparative cost advantages of agricultural production systems. Within a Coordination and Support Action funded by the 7th research framework of the EU (www.agree.aua.gr) a consortium from seven European countries identified opportunities, constraints and research needs concerning energy efficiency in agriculture.*

Key words: *energy efficiency, precision farming, reduced tillage.*

1. INTRODUCTION

Within the EU-27 agricultural production requires about 1.07 EJ of energy, including indirect energy embodied in production supplies (inorganic fertilizers, pesticides, feed, plastics, etc.) and direct energy (i.e. fuels, natural gas, biomass) for heating and electricity. In the total primary energy consumption, the percentage of direct energy use in agriculture is estimated, on the average at 61%, but in the greenhouse sector in northern countries it may be much higher, up to 98%. Indirect energy use has often been neglected and subscribed in other sectors in national statistics. For example fuel used in agriculture is accounted in EU statistics in the transport sector. Nevertheless, a change in energy prices will affect both, direct and indirect energy costs. Agriculture as a primary production sector relies very much on the use of energy. Therefore, energy price changes may affect the agricultural sector strongly. Energy efficiency measures have the potential to mitigate adverse effects on the agricultural sector and also negative externalities which are associated with energy use.

Improved energy efficiency can be achieved either with lower energy input (without or with limited impact on yields) or with higher productivity resulting in higher yields with the same or even more energy use. Therefore, improved energy efficiency can be realized with either increased or decreased energy inputs depending on the input-output relationship. Generally, better energy efficiency can be achieved with the use of improved technologies, but also straightforward adjustments to the level of energy input into agricultural systems can contribute to better energy efficiency. Koning et al. [1] have given an overview of the historical food production showing that subsequent innovations in agricultural production systems have led to an increase in (direct and indirect) energy use, while energy efficiency has increased. However, a review on recent studies on energy productivity in several countries showed mixed results (Pelletier et al. [2]).

Energy efficiency measures can be beneficial for farmers and the environment, but there can also be trade-offs that limit the adoption of energy efficiency measures or could introduce unintentional side-effects. In same situations however, even if energy efficiency measures prove to be a win-win situation there still may be obstacles that limit the adoption of the measures by farmers. For example a farmer may not invest in an economically profitable technology even though the economic benefits are clear. This may be because of farmer's preferences for a particular technology, the comparative advantage of different technologies or even the impossibility of attracting the required financial investment. Possibly a farmer is more interested to invest in other technologies, which promise even higher margins than the economically profitable energy efficiency measure. Therefore, not only the profitability but the comparative advantage of the energy efficiency measure needs to be taken into account to show the adoption probability. Of course this comparative advantage is subject to the individual possibilities and options of a farmer. Hence, often no general statement can be given for each of the individual energy efficiency measures. Nevertheless, opportunities and possible constraints can be identified, which indicate research and development potentials of energy efficiency measures.

This paper reflects opportunities and constraints of energy efficiency measures in agriculture and identifies research needs for a sustainable energy efficient agriculture in Europe.

2. MATERIAL AND METHODS

In order to identify opportunities and constraints of energy efficiency across Europe an inventory on energy efficiency measures in six European countries including their energy saving potentials was developed. The analysis of the energy use efficiency of the measures includes direct and indirect energy associated with the production of the agricultural product. The inventory analyses are based on a cradle-to-farm-gate analysis, taking into account all costs needed to produce the agricultural products, following ISO 14040.

In depth analyses have been performed for 47 energy efficiency measures for arable cropping systems, animal husbandry systems, greenhouse production systems and agro-forest production systems. For each of the energy efficiency measure energy savings and impacts on farm economy and greenhouse gas mitigation potential were estimated. The energy efficiency indicator is best expressed as the ratio of energy use per cultivation area (GJ ha-1) and energy use per unit of product (GJ t-1).

Energy use and productivity have been established for those agricultural products which have a decisive role in the EU foodstuff production, including:

- arable production of wheat, potatoes, sugar beet, cotton, and sunflower;
- greenhouse production of tomatoes, sweet pepper and cucumber;
- perennial crops such as vineyard and olive trees;
- livestock such as dairy cows, pigs, and broilers.

Energy use was established based on average production figures or best estimates (should the averages be unavailable). For each type of production, the volume of inputs was included along with the final energy consumption (FEC) and primary energy consumption (PEC). The parameters/energy equivalents used to convert the physical data of the input use into the energy data were preferably drawn on the BioGrace database (www.biograce.net). In the case of a country with a typical production system, the relevant references are given. These parameters allow converting the physical inputs into FEC and PEC figures. Some conversion factors, however, have been specific for a country, such as the PEC of electricity which depends on the national energy mix used to produce electricity.

Direct energy inputs include all the energy carriers used directly in the agricultural production process, including electricity, refined petroleum products (diesel, natural gas, and others), natural gas based fuels as well as biomass. Electrical energy used for transportation and operations in the farm, lighting, electrical equipment, automation processes and farm management include also energy use for conditioning and storage of grain (Northern Europe), electrically driven fans or heaters as well as energy used for irrigation. In animal husbandry electrical energy is needed for heating or cooling the environment of the animals, feed rationing by automatic equipment, milking and milk cooling. Solid fuels, including biomass fuels (wood chips) are used for heating buildings, e.g. in livestock production and also in some greenhouses.

Indirect energy inputs, which include energy carriers used for manufacturing of production means like fertilizers, pesticides, farm machinery, agricultural plastics and farm buildings as well as seeding material and feed. The indirect energy associated with the construction of farm buildings and farm machinery has been excluded from the present study. The reason is that this would necessitate a very detailed level of data acquisition as farm buildings are very diverse in construction and a large variety of farm machinery is used in the field operations. Moreover, data on the energy associated with the construction of farm machinery is missing. Finally, the indirect energy from farm buildings and machinery has only a limited potential to contribute to energy savings in agriculture.

3. RESULTS AND DISCUSSION

3.1. Energy efficiency in different production systems across Europe

The comparison of different production systems shows different energy efficiencies (in terms of energy use per unit of product) across Europe. Figure 1 shows the variability of energy use and crop yields for wheat production. Based on these data, specific energy use in wheat production ranges from 2.1 to 4.3 GJ per ton among countries.

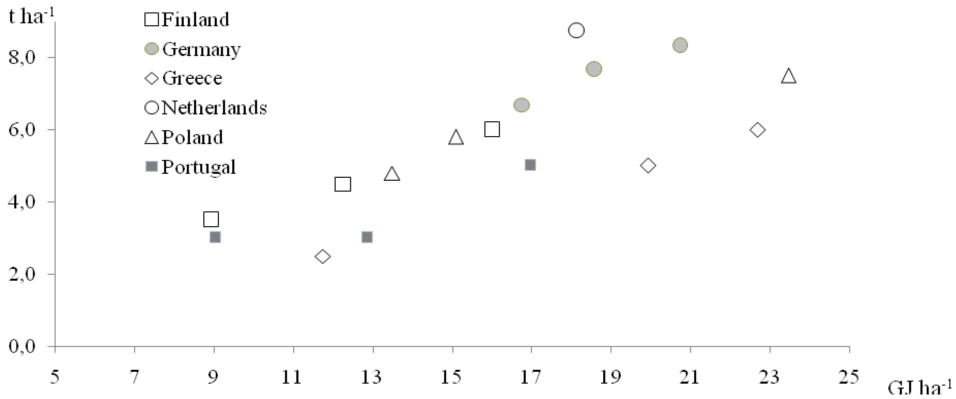

Fig. 1: Relation of total energy inputs (GJ ha-1) and crop yields of winter wheat across Europe (Data: Gołaszewski et al [3]).

The main energy input for field crops as winter wheat is associated with the use of fertilizers and diesel. Often energy (e.g. electricity) -input for irrigation, drying and/or storage is important but it depends both on geographical location and related climate, and intensity of the production systems.

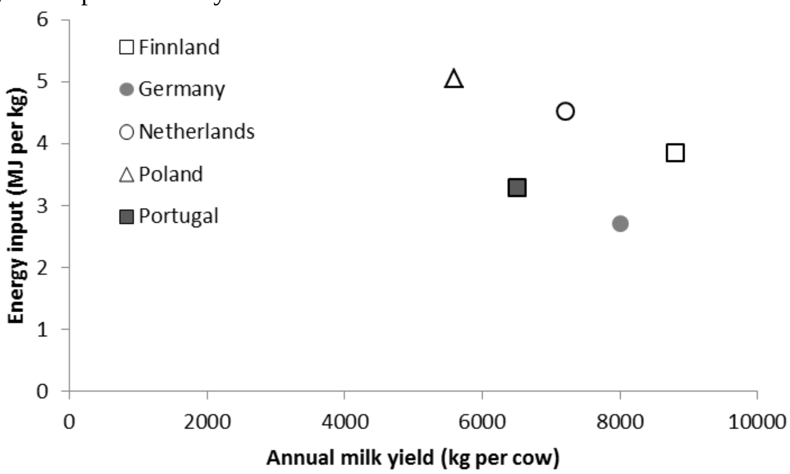

Fig. 2: Relation of total energy inputs (MJ per kg milk) and milk yield across Europe (Data: Gołaszewski et al. [3]).

Greenhouse vegetable production in Central and Northern EU countries is characterized by a very intensive direct energy input and differs significantly from the production systems in Southern EU countries. For crops grown in the Southern countries little direct energy input may be needed when grown directly on soil. However, energy use for irrigation and indirect energy inputs are more important in southern countries.

In animal husbandry systems most of the energy use is related to feed production. Furthermore, ventilation, heating (in northern countries) and cooling (in southern countries) additionally affect energy use efficiency. The energy efficiency of animal husbandry systems vary substantially across Europe (Fig. 2), but is very much a function of the management system.

3.2. Opportunities and constraints of energy efficiency measures in agriculture

In arable systems major energy efficiency measures are associated with the use of direct energy of fuel use and indirect energy use with nitrogen fertilizer use. The analysis of different case studies across Europe showed energy saving potentials from 1 % to 43 % of the total energy use (Fig. 3). The highest energy saving potential was identified with reduced tillage in Portugal. Lower relative energy saving potentials was identified by means of precision farming or implementing of efficient dryer technologies. All the selected energy efficiency measures had a positive economic effect on the net return of the production system, which correlates to some extent with the energy savings. However, energy savings can also be cost increasing, which is the case for example with suboptimal fertilizer application, which results in opportunity costs for the farmer. Even though in this case the effect is small, this energy efficiency measure would not be implemented by farmers unless they are forced to do so. Little cost saving potentials may also be a constraint for the adoption of energy efficiency measures, since investments are necessary or production structures need to be changed.

In animal husbandry systems a focus of energy efficiency measures was laid on efficient feeding strategies. These contribute to farm economic gains, energy saving and greenhouse gas mitigation effects. However, the limits of energy efficient feeding strategies in ruminant production systems should be investigated. There is evidence that the economically most efficient feeding strategy may be not effective from an energy efficiency and greenhouse gas emission point of view. These trade-offs need to be analyzed in more detail in the specific regional settings to derive strategies for energy efficient dairy and beef systems across Europe. In pig and poultry production systems most attention has been given to the heat management. While in northern Europe insulation and heat recovery is of biggest importance in southern Europe ventilation techniques and cooling is most important. Since pork and poultry production systems are the most industrialized agricultural production systems all measures on energy efficiency should be checked for compliance with the consumers' demand for animal welfare. Greenhouse production systems use a huge amount of energy especially in northern Europe, which indicates great energy saving potentials. Most of the saving measures target added insulation and heat recovery systems, which mostly are beneficial from economic and environmental perspectives. However, typically, significant investments are necessary for most efficient greenhouse systems.

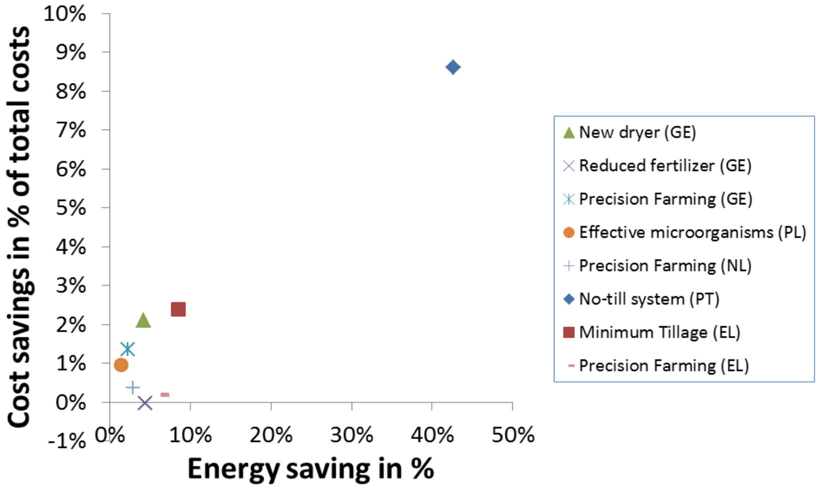

Fig. 3: Energy and cost saving potentials of different energy efficiency measures across Europe (Data: Meyer-Aurich et al. [4]).

CONCLUSIONS

Energy efficiency is important for establishing sustainable agriculture not only from an environmental but also from an economic point of view. Agriculture is most susceptible to energy price increases because direct and indirect energy use contributes to a substantial share of the production costs in agriculture. Energy efficiency measures in agriculture, however, have different opportunities and constraints which should be addressed appropriately.

In arable systems the focus of energy efficiency measures is put on diesel fuel and nitrogen fertilizer saving technologies. Precision Farming is one of the technologies, which may contribute to improved energy efficiency. The analyses showed, however, that the limited economic effect of the technologies may be a major constraint for the adoption of these technologies. Therefore, there is a research need for identifying economically viable Precision Farming solutions, which furthermore contribute to energy efficiency and other environmental benefits. Rather simpler measures, which target the fertilizer application in arable production systems have shown a strong effect on both energy saving and greenhouse gas emissions but are difficult to implement because of often negative economic effects at the farm level. In general indirect energy use has been identified as an important driver for energy use at the farm level in many cases. Especially the use of nitrogen fertilizer has been shown as a key factor in improved energy efficiency across different production systems and countries. Nitrogen is not only important in crop production systems, but also in animal production systems, since indirect energy use in animal production systems is often related to nitrogen use in feed production. In addition to the energy related effect nitrogen management has an even more important role for greenhouse gas emissions. Therefore, even though studied for long, nitrogen in agricultural systems still requires most attention when targeting a more energy efficient agriculture.

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Case study

ENERGY EFFICIENCY AND GHG EMISSIONS IMPACT FROM TRADITIONAL TO ORGANIC VINEYARD CULTIVATIONS IN GREECE AND PORTUGAL

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Abstract. *Traditional farming systems are based on achieving high yields using high inputs, targeting acceptable farmers' income. Nowadays, traditional farming shifts towards maximum possible crop yield using minimal inputs in an optimized way or towards organic farming, namely accomplishing low yield of high quality products without using conventional agrochemicals (i.e. fertilizers, pesticides). The last approach leads, in general, to lower energy consumption per unit area of land, therefore lower cost and lower greenhouse gas emissions (GHG). However, in a global perspective it has the risk of significant reduction in total production. Hence, it is vital to consider energy efficiency, namely the ratio between an input of energy and a unit of product, as a key comparison unit affecting the overall efficiency of crop farming systems in terms of energy and GHG emissions. In the present paper, two show cases of vineyard cultivations are presented to illustrate the energy efficiency and GHG emissions impact when switching from traditional to organic vineyard cultivations in Greece and Portugal. In the Greek vineyard case, organic farming leads to significantly lower grape yield (31%) resulting in a 0.4% reduction of energy efficiency and a 6.7% reduction of GHG emissions. In the Portuguese vineyard case, organic production results in a grape yield decrease of approximately 21%, leading to lower energy efficiency (4.7%), also reflected in GHG emissions (2.7%).*

Key words: *vineyard cultivation, organic farming, energy efficiency, GHG emissions*

1. INTRODUCTION

Agriculture as a primary production sector relies very much on the use of energy. Even if the agricultural sector accounts for 3.7% of the total energy use in EU-27 (EEA, 2012), which seems insignificant, it should be noted that in many countries national statistics record as energy use in agriculture only energy inputs during the cultivation period (direct energy use). On the other hand, energy use for the production of input materials (indirect energy use), such as fertilizers and pesticides and plastics, is recorded under the industrial sector and fuel use in the transport sector. If other activities (e.g. transport of raw materials) linked to the production of these materials are also considered, then the relative importance of this phase shows significant interest.

If both direct and indirect energies are considered in an agricultural production system, then it becomes clear that a significant amount of total energy is required for the production of agricultural products and that energy saving should also be considered in this sector, as in most energy consuming sectors (e.g. electrical appliances, automobiles, buildings, etc.). The best way to save energy is to improve the energy efficiency of the whole system.

According to the Energy Services Directive 2006/32/EC, there is a need for improved energy end-use efficiency in all energy consuming systems. In Article 3 of the same Directive, energy efficiency is defined as the ratio between an output of performance, service, goods or energy, and an input of energy.

There are two ways to obtain improved energy efficiency: either by reducing energy input or increasing yield or a combination of both. Thus, improved energy efficiency can be realized with either increased or decreased energy inputs depending on the input-output relationship.

Traditional farming systems target on high yields without considering the amount of inputs used during the cultivation period. The only consideration is the impact of these inputs on the final profit of the farm. However, this practice has been the subject of strong questioning during the last two decades as the negative environmental and public health impacts of such farming systems are very high. Under the consideration of these impacts, new farming systems have been adopted. Among them, organic farming is associated with lower yield and better quality, which excludes or strictly limits the use of synthetic fertilizers and pesticides.

Organic farming seems to be an ideal farming system on a land area basis (lower energy consumption per unit area of land), but this is not the case on a yield basis. In a global perspective it has the risk of significant reduction of total agricultural production. Hence, as a key comparison term affecting the overall efficiency of crop farming systems, it is vital to consider energy efficiency.

Vines are one of the most important perennial crops for Greek and Portuguese agriculture. In general, vineyards are cultivated using traditional methods. Organic farming is not widely applied yet as farmers believe that high chemical inputs ensure high yields and profits. However, there is a tendency recently to switch to organic farming as a result of higher product prices, especially for high quality exported certified wines. It is a practice encouraged by European policies with advantages concerning environmental protection. With this production system, productivity reduction is expected, but net return could be satisfactory since the market prices are higher.

Organic farming relies on a number of practices designed to minimize the impacts on the environment, while ensuring that the agricultural system operates as naturally as possible. Typical organic farming practices in vineyards include the limitation in the use of synthetic pesticides and fertilizers and takes advantage of on-site resources, such as livestock manure for fertilizer. In addition, organic farming could help to conserve water

(Altieri, 1992) in arid and semi-arid areas like many regions in Southern European countries as Greece and Portugal, and reduce GHG emissions (Dalgaard et al, 2001).

In this work the traditional farming of a vineyard located in the "Sterea Ellada" region, Greece and a vineyard in the "Alentejo" region, Portugal, was compared against the respective organic farming in terms of energy efficiency and respective GHG emissions.

2. MATERIAL AND METHODS

Apart from productivity, energy consumption is also directly related to environmental impacts and especially to GHG emissions. Therefore, it is worth considering both aspects when a new production system is proposed to replace an existing one. The energy efficiency and the environmental analysis in this work are based on a "cradle to farm gate" analysis, taking into account all inputs used, costs needed and emissions released to produce the agricultural products.

Traditional and organic vineyards in the Greek region "Sterea Ellada" and the "Alentejo" region of Portugal were studied in terms of energy efficiency and the respective GHG emissions production based on information provided by farmers and data found in literature.

In order to model potential trade-offs between energy savings and GHG emissions it was necessary to model the new production system (organic farming) with simple spreadsheet based models. Their frameworks were constructed based on selected show-cases for typical vineyard cultivations in the two countries. The models were modified according to the variety and the agricultural practices followed in each case study and the location of the production system.

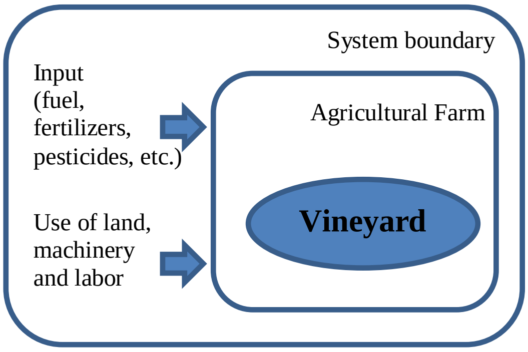

Fig. 1: System boundary of energy and environmental assessments.

Instead of modeling only the production systems, the show case models were studied within a farm level framework, thus relating energy and GHG emission with final yield. In order to provide consistent results, the same system boundaries for all energy and environmental assessments were selected. The farm gate was considered as the ultimate boundary of the analysis of the trade-offs (Figure 1), because the show case analyses processes on the farm may differ. The calculations of the energy savings and GHG emissions with the energy efficiency measures were based on assumptions drawn, if not stated otherwise, from the Biograce database (www.biograce.net).

2.1. Case study vineyard in Greece

The first step regarding the case study vineyard from “Sterea Ellada” region was to develop records of the traditional agricultural practices and total inputs using data from a personal interview with the owner farmer. The same vineyard was then assumed to be converted into an organic system using data according to international and national literature.

2.1.1. Traditional vineyard

The basic scenario is a vineyard with mean plant density of 3,000 plants ha^{-1}, with a compass of 2.7 × 1.2 m. The vineyard life time was assumed to be 20 years, with the first 4 years counting as installation period of low yield. The typical traditional cultivation actives are described below:

The vineyard installation is initiated with several operations for the soil preparation (with the use of plough for deep ploughing, heavy cultivator, light cultivator), followed by a fertilization using 30 kg ha^{-1} N, 40 kg ha^{-1} P and 40 kg ha^{-1} K. The plot is marked and holes are opened for the vines. A system of metal tutors is installed. These operations are considered for the first year of installation.

During the first growing period of the vine crops, vineyards are sprayed with *Bacillus turingiensis*, sulphur, copper, Topsin M (thiophanate methyl 97% w/w), dithane M-45 (mancozep 72% w/w), thiodan (endosulfan 47% w/w). For weed control, the soil is cultivated with light cultivator and sprayed with Paraquat (20% v/v) and Glyphosate (36% v/v). Two irrigation applications using drip irrigation systems are applied (total water quantity 1,600 m^3 ha^{-1} yr^{-1}). Fertilization is applied together with the irrigation (fertigation) with 30 kg ha^{-1} yr^{-1} N, 40 kg ha^{-1} yr^{-1} P and 40 kg ha^{-1} yr^{-1} K.

After the fourth year, the vineyard reaches the regular production. During the regular period vineyard cultivation techniques are mainly related to soil maintenance and weed control, fertilisation, irrigation, pruning, thinning fruits, crop protection against pests and diseases, and harvesting. Pruning, namely leaving two eyes in every branch, is performed in May in order to control excessive vegetation and keep the final grape production to high levels. The vineyards are sprayed with *Bacillus turingiensis*, sulphur, copper, Topsin M (thiophanate methyl 97% w/w), dithane M-45 (mancozep 72% w/w), thiodan (endosulfan 47% w/w) during spring time. For weed control (March - April), the soil is cultivated with light cultivator and sprayed with Paraquat (20% v/v) and Glyphosate (36% v/v). Every year, one to two irrigation applications using drip irrigation systems are applied (between May and July with total water quantity 800 m^3 ha^{-1} yr^{-1}). Fertilization is applied together with irrigation with approximately 55 kg ha^{-1} yr^{-1} N, 75 kg ha^{-1} yr^{-1} P and 75 kg ha^{-1} yr^{-1} K.

This farm is equipped with all the necessary equipment, such as a 50 kW tractor, a rigid cultivator, a sprayer, a trailer, a fertilizer spreader, etc. Harvest is performed manually by the end of September (during the first 4 years the mean yield was 4 t ha^{-1} yr^{-1}, while during the next 16 years was 14.7 t ha^{-1} yr^{-1}).

2.1.2. Organic vineyard

Organic farming in the vineyard reduces fuel consumption by 20%, because several agricultural practices of the conventional farming are not used (an assumption based on the work of Kavargiris et al., 2009). No chemical pesticides are applied, whereas allowed fungicides (copper and sulfur) are applied, but 34% less than in the traditional farming system [6]. In addition, fertilizer application is reduced by 45.7% [6]. All other agricultural practices are the same as in the traditional system. The average yield is assumed to be reduced by 31% due to lower inputs and higher disease and pest impact on the crop [6].

2.2. Case study vineyard in Portugal

The first step regarding the case study vineyard from the “Alentejo” region was to develop records of the traditional agricultural and organic practices and total inputs using data from a personal interview with the farmer.

2.2.1. Traditional vineyard

Mean plant density is 4,000 plants ha^{-1}, with a compass of 2.5 × 1.0 m. The vineyard installation is initiated with several operation for the soil preparation, followed by a fertilization using 200 kg ha^{-1} of P and K complemented with the application of 500 kg ha^{-1} of an organic fertilizer. Soil is marked and holes are open for the vines. The system of tutors is installed. These operations take place only in the first year and therefore in the calculations followed the respective values of energy consumption and GHG emissions produced are divided considering the total lifetime of the vineyard, which was assumed to be 20 years.

Vineyard cultivation techniques are mainly related with soil maintenance and weed control, fertilization, irrigation, pruning, thinning fruits, crop protection against pests and diseases, and harvesting. Fertilization is approximately 35 kg ha^{-1} N, 80 kg ha^{-1} P and 15 kg ha^{-1} K. In early spring an herbicide is applied along the crop line (glyphosate), and usually in April begins the application of several pesticide treatments that continues until August, depending on the climate conditions. In Portugal the wine technology begins in the field. Grape production is reduced in the field with the pruning of fruits in early growth stages to decrease yields in order to attain better fruit quality required for producing quality wines. Therefore, rigorous pruning is performed in May, in order to control excessive vegetation and to define the final grape production according to the targets set by the farmer regarding quantity and quality of the grapes.

The vineyard is irrigated by a drip irrigation system. The vines are irrigated from May to July with an average annual quantity of 2,000 m^3 ha^{-1} of water, and with the application of liquid fertilizer (fertigation). The amount of applied water depends on the meteorological conditions of each year, but is mostly supplemental irrigation practices. This farm is equipped with all the necessary equipment, such as tractors (the farmer uses tractors with 70hp to 145hp, for the different field operations performed along the crop cycle), a harvesting machine, sprayer, cut grass, vine breaks, etc.

Grape harvest is from August to September. This vineyard, in its full production stage, produces 7 t ha^{-1} yr^{-1} of grapes yield for quality wine production.

2.1.2. Organic vineyard

In this farm the main difference comparing with the traditional system is the exclusive use of organic fertilizers and the non-use of synthetic pesticides (only sulphur and copper are used). The production is 5.5 t ha^{-1} yr^{-1} of grape yield for quality wine. Farm machinery is the same as in the basic scenario.

2.2. Inventory

2.2.1. Inputs

A spreadsheet was prepared with an inventory of all vineyard cultivation inputs in Greece and Portugal (Table 1). It must be pointed out that installation period corresponds to the period after initial planting until the year of regular production yields (4 years) and the operation period corresponds to the regular production period.

Table 1: Inventory of the traditional vineyards.

Inputs		**Greece**		**Portugal**	
	Unit	Install	Operation	Install	Operation
Plants		3,000		4,000	
Metal tutors	kg ha^{-1}	550		375	
Fertilizers (synthetic)					
Nitrogen	kg ha^{-1}yr^{-1}	55	55	-	35
Phosphorus	kg ha^{-1} yr^{-1}	75	75	200	80
Potassium	kg ha^{-1} yr^{-1}	75	75		15
Fertilizer (organic)					
Livestock manure	kg ha^{-1}			500	-
Pesticides					
Herbicides	kg ai^{-1} ha^{-1} yr^{-1}	-	2.00	-	0.87
Fungicides	kg ai^{-1} ha^{-1} yr^{-1}	4.56	9.49	-	25.67
Acaricides	kg ai^{-1} ha^{-1} yr^{-1}	-	-	-	0.08
Insecticides	kg ai^{-1} ha^{-1} yr^{-1}	-	-	-	3.14
Irrigation					
Electricity use	kWh ha^{-1} yr^{-1}	880	440	-	660
Field operations					
Diesel use	l ha^{-1} yr^{-1}	36	34.6	400	86.5

2.2.2. Outputs

Table 2 shows the production yield of the Greek and Portuguese. As expected the average yield during the first installation period is significantly lower than in the regular production period.

Table 2: Annual production yield of the traditional vineyard.

		Greece		**Portugal**	
Output	Unit	Period			
		Install	Operation	Install	Operation
Grapes	t ha^{-1}yr^{-1}	4.00	14.70	-	7

2.2.3. Data sources and main assumptions

The primary energy and the respective GHG emissions for each of the considered inputs are shown in Table 3.

Table 3: Primary energy of inputs.

Input	Primary Energy	Unit Primary Energy	Total GHG emissions	Unit GHG emissions
Plant[1]	2.61	MJ kg^{-1}	0.276	$kgCO_2eq\ kg^{-1}$
N fertilizer[1]	48.99	MJ kg^{-1}	5.880	$kgCO_2eq\ kg^{-1}$ N
P_2O_5 Fertilizer[1]	15.23	MJ kg^{-1}	1.010	$kgCO_2eq\ kg^{-1}\ P_2O_5$
K_2O Fertilizer[1]	9.68	MJ kg^{-1}	0.576	$kgCO_2eq\ kg^{-1}\ K_2O$
Pesticide[1]	268.40	MJ kg^{-1}	10.970	$kgCO_2eq\ kg^{-1}$
Diesel Fuel[1]	49.99	MJ kg^{-1}	3.640	$kgCO_2eq\ kg^{-1}$
Electricity (Greece)[2]	4.53	$MJ_pNR\ MJ^{-1}$	2.086	$kgCO_2eq\ MJ^{-1}$
Electricity (Portugal)[3]	2.44	PE GWh^{-1}	0.5	$kgCO_2eq\ MJ^{-1}$

[1]Biograce V4 (2012), [2]Ecoinvent (2007), [3]DGEG (data from 1990 to 2006).

Pesticides require the highest energy for their production, resulting in most of the GHGs produced. Diesel fuel and nitrogen fertilizers follow with minor difference between them. Table 3 clearly shows that non-renewable energy required and GHG emissions for electricity production in Greece are very high. These figures are much higher than the EU average (Ecoinvent, 2007: UCTE average is 1.6 $MJ_pNR\ MJ^{-1}$ and 0.125 $kgCO_2eq\ MJ^{-1}$ respectively), as the electricity grid in Greece is mainly supported by low efficiency coal (lignite) and oil production units, which result in high energy input and GHG emissions.

3. Results and discussion

3.1. Current Energy and GHG emissions profile

Fig. 2 shows the energy and GHG emissions profile of the traditional vineyards in Greece and Portugal. In Greece, the highest energy consumer and GHG emission source is the electricity for irrigation, due to the used fossil fuel energy mix. The second most important energy consumer are the fertilizers, followed by pesticides and fuel. As for GHG emissions, electricity count for almost half of the total GHGs of the system followed by fertilizers. Pesticides and fuel are on the same level.

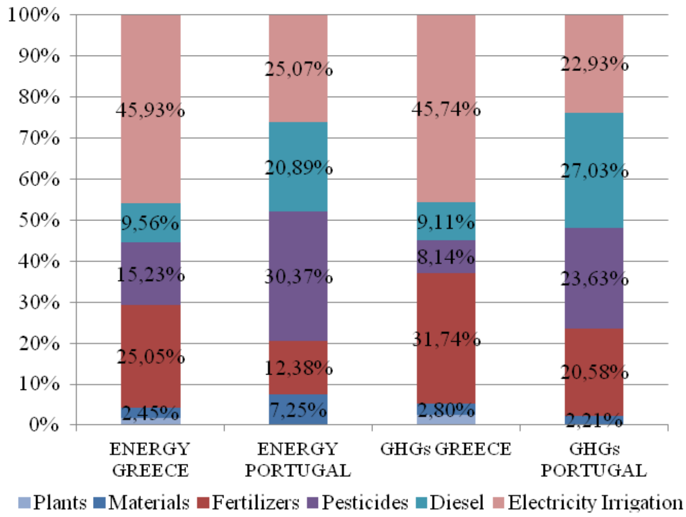

Fig. 2 Energy profile and GHG emissions of the conventional vineyard

On the other hand, in Portugal the main energy consumer are the pesticides, which could be explained by the significant use of fungicides due to wet portuguese climate during spring time. Electricity for irrigation comes second and diesel fuel third. Regarding GHG emissions, diesel takes over first place, leaving pesticides in the second place, because the ratio between energy and GHGs for pesticide production is in favor of energy. Fertilizers remain fourth in importance like with energy consumption, but they contribute more to GHG emissions (ratio energy/GHGs is in favor of energy).

3.2. Energy efficiency impact (traditional - organic)

Organic farming in the Greek vineyard results in (an assumed) significantly lower grape yield (31%), which has a minimal impact on the final energy efficiency that was slightly lower than in the conventional production, as the energy consumption per unit of product was increased from 1,738 MJ t^{-1} of grapes to 1,745 MJ t^{-1} of grapes (increase of the ratio energy consumption per unit of product by 0.4%). The fact that no chemical fertilizers and pesticides are applied is not enough to cover the assumed high loss of grapes production. Regarding organic farming in the Portuguese vineyard, the yield is also reduced significantly (21%). Energy efficiency was lower than in the conventional production as the energy consumption per unit of product was increased from 3,647 MJ t^{-1} of grapes to 3,821 MJ t^{-1} of grapes (increase of the ratio energy consumption per unit of product by 4.7 %). It can be seen that, in line with the Greek vineyard, zero use of chemical fertilizers and pesticides is not enough to compete with the effect of such a lower yield.

The Portuguese traditional agricultural practice requires 110% more energy than the Greek respective practice (1,738 MJ t^{-1} vs. 3,647 MJ t^{-1}), which increases to 119% in the organic farming system (1,745 MJ t^{-1} vs 3,821 MJ t^{-1}). The main reason for this is that the average yield of the Portuguese vineyard (7 t ha^{-1}) is half the Greek (14.7 t ha^{-1}), because Portuguese farmers prune their vine crops more rigorously to achieve better grape characteristics as compared to their typical characteristics for the production of high quality wines.

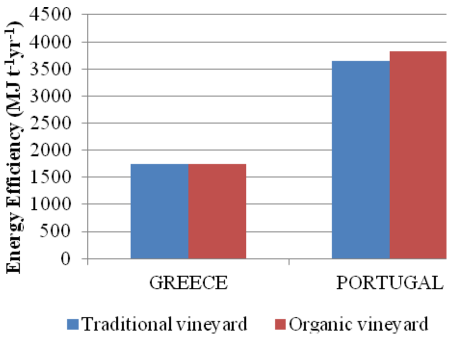

Fig. 3: Energy efficiency alteration (MJ/t/yr) from conventional to organic vineyard in Greece and Portugal.

3.2. Greenhouse Gas Emissions impact (traditional - organic)

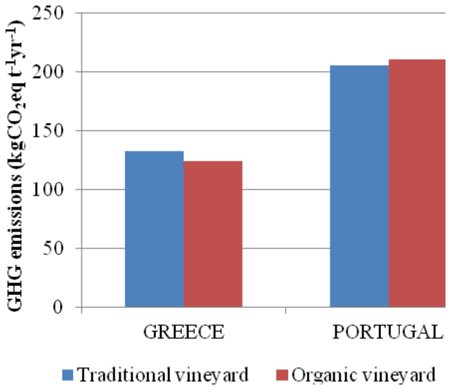

Fig. 4: GHG emissions alteration ($kgCO_2eq\ t^{-1}\ yr^{-1}$) from conventional to organic vineyard in Greece and Portugal.

Fig. 4 shows the GHG emissions impact for both case studies of Greece and Portugal. In Greece, GHGs are reduced by 6.7%, although energy use increases. This is explained by the fact that the pesticides and chemical fertilizers that are not applied are major contributors, during their production process, to significant quantities of GHG emissions. At the same time manure (the chemical fertilizer substitute) is not taken into account in the GHG emission calculations, as, even if it is not used in the vineyard, it is already left in piles to be composted.

On the other hand, in Portugal, GHG emissions are increased by 2.7%, following the trend of lower energy efficiency, having as the main reason the yield decrease.

The Portuguese traditional agricultural practice produces 55% more GHG emissions than the Greek respective practice (133 $kgCO_2eq\ t^{-1}$ vs. 205 $kgCO_2eq\ t^{-1}$), which increase to 70% in the organic farming case (124 $kgCO_2eq\ t^{-1}$ vs. 211 $kgCO_2eq\ t^{-1}$). The main reason for this result is the same as in the energy analysis above (yield of the Portuguese vineyard is half of the Greek case study).

3. CONCLUSIONS

A comparison, based on the energy efficiency per unit product and the respective GHG emissions, is presented between traditional and organic farming of two vineyards located in the “Sterea Ellada” region of Greece and the “Alentejo” region of Portugal. In Greece, swift from traditional grape production to organic farming gives almost neutral results in terms of energy efficiency, but positive results regarding GHG emissions (reduction by 6.7%), as chemical fertilizers and pesticides are replaced by less GHG productive inputs. In the case of Portugal, organic farming results in lower energy efficiency by 4.7% and increases GHG emissions by 2.7%.

Due to half yield production, the vineyard in Portugal requires more than two times the energy used in Greece to produce the same quantity of grapes. For the same reason, the vineyard in Portugal also produces higher GHG emissions (more than 50% increase).

The introduction of organic production system affects at acceptable levels energy efficiency and GHGs in both countries. It has advantages and it should be considered as an alternative option. Future studies should seek to find adapted varieties with high productivity and improved technologies for organic farming that could help obtain better results. The challenge for the future in both countries will be to achieve better productivities for organic grapes while maintaining a high quality wine standard.

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Original scientific paper

ENERGY EFFICIENT TECHNOLOGY AND TECHNICAL SYSTEMS FOR BIOMASS COLLECTION FROM CROP PRODUCTION

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Abstract. *Energy plays a key role in the economic growth and economic structure of a country whether it is developed, less developed and underdeveloped country. It is estimated that the total amount of crop residues in crop production ranges from 9.55 to 13 million tons, and the expected amount of crop residues that can be used as fuel is from 3.06 to 4.17 million tons. The increase of the energy efficiency is a constant task for the researchers, businesses and business associations. The aim of this paper is to show the energy balance of the technological and technical systems in the process of collecting biomass as well as to determine its share in the total energy balance of biomass and total biomass quantities available. The experiment showed that with the increase of transportation distance from 5 to 15 km, fuel and energy consumption is increasing for more than 80% together with the 60% lowering of fuel consumption per unit of transportation distance. Having in mind the fact that the energy value of wheat, corn and soybeans straw varies from 12 to 15 MJ kg^{-1} and that the actual average straw yield per hectare in conditions of PKB corporation is around 2.5 t ha^{-1}, then converted to energy is around 30 GJ/ha. This imposes a clear conclusion that the energy cost of collection and transportation of materials that varies from 297 to 570 MJ ha^{-1} can be characterized as more than modest*.

Key words: *biomass, renewable energy, energy efficiency, crop residue*

1. INTRODUCTION

Since the energy in any form, is the basis for every mankind activity, over the years there has been continuous increase in the energy demand and its consumption. On the other hand, primary energy sources do not show trend to be increased, at the global level

[3]. Limited supply of fossil fuels, especially crude oil, urges mankind to find substitute energy carriers. The lack or abundance of energy, are determined by the direction of technology and economics. This is particularly evident if we consider that in our region Balkans and worldwide, energy obtained by organic conversion is available, but not exploited as much. World trends in the use of renewable energy sources show that the developed countries are rapidly orientating themselves to the intensive use of all available renewable energy sources. The European Union has decided that till 2020, 20% of the total commercially available energy should come from biomass. In the European undeveloped countries this percentage goes to 5% [3]. Rozentrater et al. [4] attempted to look at the complexity of the problem of collecting crop residues in crop production for their energy use. They considered actual harvested straw yield and the effect of the crop residues on the soil fertility. They provided a rough estimation that if about one-third of the crop residues would be removed, this would not have negative effects on the fertility of the land. The main crop production provides the same or higher quantities of crop residues in relation to the grain. In some regions of European Union, the secondary raw materials (straw, husks…) have taken their functional position in the further energy production processes. In the same places, these materials are the raw ballast, and the straw is burned in the field as the most common solution. This solution is unacceptable, because it destroys the productive land fauna. [5]

The total amount of crop residues in Serbia is around 9.55 million tons. Expected amount of crop residues that can be used as a fuel is 3.06 million tons. Residue of grain crops (wheat, rye, barley) account for about 50%, corn to 37%, and oil crops (sunflower, soybean, canola) about 13% [1] and [8]. Annual energy potential of the presumed residues biomass crops is about 40 000 TJ [6]. Biomass (crop residues is a type of biomass) is a raw material that can be used for different purposes. It could be fertilization (by ploughing), processing for animal feed, bedding for livestock and industrial processing. As there are so many utilizations of biomass, energy production uses only the portion of biomass that cannot be economically used for other purposes. According to some estimates, this percentage goes up to 40% of the total crop residues [9]. The energy crisis has drawn attention to the fact that the heating value of approximately 3 kg straw corresponds to the heat value of one kilogram of fuel oil [7]. Approximate economic analysis indicated that the ratio of the value of both energies puts straw in favor [2]. Most of the crop residues are baled. Bales are bind with the natural or synthetic binder or with the mash. The important features of the bale are its density and storage density which ranges from 120–150 kg m^{-3} depending on the type of bale. It depends on the number of bales of straw in 1t, and thus indirectly affects the characteristics of transport equipment [10].

The aim of this paper is to show the energy balance of the technological - technical systems of process and collecting biomass as well as its share in the total energy balance of biomass, to thereby comprehend the total biomass potential from crop production.

2. Material and methods

The study determines the basic characteristics of crop production on farms Agricultural Corporation Belgrade ("PKB") such as:

- Grain yield - as the basis of the biomass quantity determination from crop production,

- Energy inputs in the production of biomass on the basis of total and hourly fuel consumption in the process of collection with 5 measurements (harvesting in two options - square and round bales), transportation (three types of transport distances, 5, 10 and 15 km).

Energy parameters are obtained using the following measurement methods and procedures:

- Power on PTO shaft (TRC MMN1 digital device for measuring engine speed and torque on the PTO shaft of the OECD Standard Code 2);
- Speed - real (v) (chronometry method and calculation method);
- Fuel consumption per hour (Qh) (obtained by the method of volume gauge);
- Specific fuel consumption (calculation method);
- Energy consumption (computational method);
- Productivity (chronographs and calculation method);

Mathematical model of optimal technological and technical system was developed, using linear programming (SIMPLEX). To set up the mathematical model the following phrases were used:

Indexes: n – aggregate type

X_i – system for baling i-type, i=1,2,...,n

Limitations: A_i – technological energy consumption

R_i – fuel consumption

M_i – total fuel energy

H_i – productivity of transport

H_i – productivity

The coefficients in the limitations: a_i – fuel consumption

r_i – energy consumption

m_i – fuel energy

h_i – number of bales per hour of work

d_i – ha/h

The coefficients of the criterion function: B_i – fuel consumption

C_i – energy consumption

The criterion of optimality

Minimal energy consumption $$\text{Min } Z = \sum_{i=1}^{n} CiXi$$

Max fuel efficiency $$\text{Min } Z = \sum_{i=1}^{n} BiXi$$

The mathematical model should, practically, be the same for each criterion, but would have to get to the rotation restrictions, limitations and coefficients of function criteria. One of the conditions in the model is also: $B_i, C_i, A_i, R_i, M_i, H_i, D_i \geq 0$

2.1. Experimental set up

Technical characteristics of the investigated machine-tractor for the collection of plant residues are shown in tables 1 and 2. The first tractor, Fendt 920 (6,871 l engine MAN

DO836LE501) provides at least 3% additional power which overcomes the load without changing gear. The other tested tractor had a 4 l Perkins 1004-40T. Thanks to the torque reserves of 33% and 28% respectively, tractors are able to fulfill all the requirements in performing field operations.

Vicon RV-1901 Press baler has an adjustable bale diameter from 0.8 to 1.85 m with a maximum width of 1.2 m. Depending on the amount of straw and the combine harvester width it can group two or three cutting rows. Working speed is 10-12 km h^{-1}, in rare cases up to 15 km h^{-1}. Krone Big Pack VFS chamber 890 press baler has a cross-section of 0.8 x 0.9 m with variable length from 1 to 2.7 m. As in the previous case it can group two or three cutting rows. Working speed of this press baler goes up to 15 km h^{-1}. Weight of both types of bales is in the range of 250-300 kg.

Table 1 Technical characteristics of the balers

Characteristics	Krone Big Pack 890	Vicon 1901
Width and height of the channel /min diameter bales [mm]	800 x 900	800
The length of /max diameter bales [mm]	1 000 – 2 700	1850
Width [mm]	1 950	1780
Working width[mm]	9 140	4120
Height [mm]	2 910	2790

Table 2 Technical characteristics of used tractors

Technical characteristics of used tractors	Ghibli 100	Fendt 920
Engine power [kW]	68	154
Speed at max. power [min^{-1}]	2200	2150
$M_{max.}/n_{Mmax}$ [Nm min^{-1}]	387/1400	960/1400
Specific effective consumption fuel q [g kWh^{-1}]	240	218
Energy supply in relation to the structural mass [Kw t^{-1}]	17.80	20.44
Specific weight without ballast [kg kW^{-1}]	56.17	56.80
Specific weight with ballast [kg kW^{-1}]	-	91
Weight without ballast [kg]	3820	8750
Weight with ballast [kg]	-	14000

In the experiment tractor Fendt 920 worked with a press Krone Big Pack 890 and tractor Landini Ghibli 100 with Vicon RV-1901.

3. Results and discussion

This chapter analyzes the energy parameters, such as hourly fuel consumption, fuel consumption per unit of area, energy consumption per unit of area and per liter of fuel. All these parameters were analyzed through the tractor pull capacity in the actual operation of pressing straw with two different technical solutions in the same locations and approximately the same conditions.

Tractor-machine sets consisting of a tractor Fendt 920 and Krone Big Pack 890 VFS, and tractor Landini Ghibli 100 with Vicon RV-1901, achieved the results shown in Tables 3, 4 and 5.

Table 3: Fuel consumption in the process of baling.

Type of bale	Aggregate		Fuel consumption [l h^{-1}]				
	Tractor	Baler	1	2	3	4	5
Large square	Fendt 920	Big Pack VFS 890	12.8	12.9	13.1	12.9	13.2
Large round	Landini Ghibli 100	Vicon RV-1901	6.1	6.0	5.9	5.8	6.1

Table 4: Aggregate productivity.

Type of bale	Aggregate		Aggregate productivity [ha h^{-1}]				
	Tractor	Baler	1	2	3	4	5
Large square	Fendt 920	Big Pack VFS 890	3.5	3.55	3.45	3.55	3.4
Large round	Landini Ghibli 100	Vicon RV-1901	1.25	1.15	1.20	1.30	1.10

Table 5: Number of bales achieved in a given time.

Type of bale	Aggregate		Number of bales for 1 h of work				
	Tractor	Baler	1	2	3	4	5
Large square	Fendt 920	Big Pack VFS 890	25	24	24	26	24
Large round	Landini Ghibli 100	Vicon RV-1901	13	12	13	13	11

Average fuel consumption with Krone Big Pack baler VFS 890 is 12.98 l h^{-1}, and with the baler Vicon RV-1901 5.98 l h^{-1}. Performance of Krone Big Pack VFS 890 is 24.8 bales per hour of work, and of Vicon baler is 12.4 bales per hour of work. Average number of bales per hectare is 8.9. Fuel consumption per unit area in the working process with a press Krone Big Pack VFS 890 is 35% lower if compared with the other observable press.

Average fuel consumption of the tractor Landini Ghibli 100 using the baler Vicon RV-1901 (Table 6, Fig. 1) is 5 l ha^{-1} with the effect of 1.2 ha h^{-1}, the power consumption of 13.84 kWh ha^{-1}, ie. 49.83 MJ ha^{-1} and fuel utilization coefficient of 27%.

Table 6: Energy consumption and percentage of utilization of fuel tractor Landini Ghibli 100 and Vicon RV-1901.

No.	E_{ha} [kWh ha^{-1}]	Q_{ha} [l ha^{-1}]	Energy technology [MJ ha^{-1}]	The total energy Fuel E_{ha}[MJ ha^{-1}]	Coefficient fuel efficiency[%]
1.	12.63	4.88	45.47	180.36	25.21
2.	15.30	5.21	55.10	192.56	28.61
3.	12.21	4.91	43.98	184.47	23.84
4.	12.94	4.46	46.60	164.84	28.27
5.	16.13	5.54	58.10	204.75	28.37
aver.	13.84	5.0	49.83	184.80	26.96

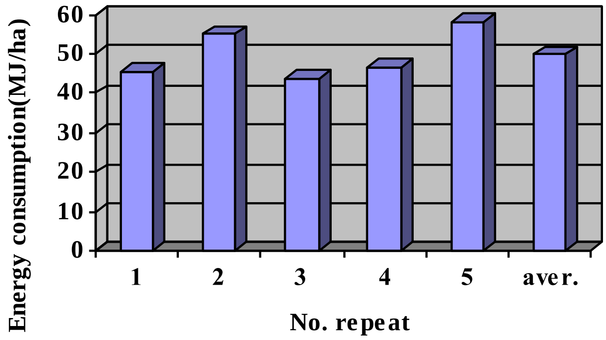

Fig. 1 Energy consumption per unit area with a baler Vicon RV-1901

Table 7 Energy consumption and percentage of utilization of fuel tractor Fendt and Krone Big Pack VFS 890

No.	E_{ha} [kWh ha^{-1}]	Q_{ha} [l ha^{-1}]	Energy technology [MJ ha^{-1}]	The total energy Fuel E_{ha}[MJ ha^{-1}]	Coefficient fuel efficiency [%]
1.	10.10	3.65	36.36	134.9	26.95
2.	11.40	3.60	41.04	133.1	30.83
3.	9.32	3.80	33.55	140.4	23.89
4.	10.74	3.60	38.66	133.1	29.04
5.	12.83	3.90	46.20	144.1	32.06
aver.	10.90	3.71	39.24	137.12	28.61

Average fuel consumption of the tractor Fendt 920 with the baler Krone Big Pack VFS 890 is 3.71 l ha^{-1} with the productivity of 3.49 ha h^{-1}. The power consumption is 10.90 kWh ha^{-1}, ie. 39.24 MJ ha^{-1} and the fuel utilization coefficient is 28.61% (Table 7, Fig. 2).

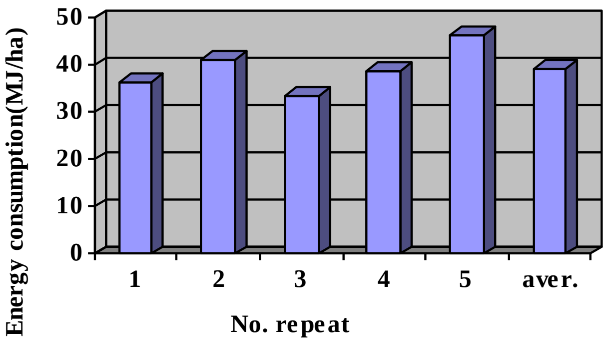

Fig. 2: Energy consumption per unit area with Krone Big Pack VFS 890.

The “PKB” Corporation transport is done by tractor Landini Ghibli 100 and a standard trailer capacity of 8-9 t and adapted trailer, exclusively for this purpose, measuring 7.2 x 2.5 m. The fuel consumption of tractor machinery couples in the transport is, at the average level of 5.78 l h^{-1}.

The results from the field show that the performance of the square bales transport is 20% higher if compared with the round bale transport. The reason for this is higher percentage of trailers capacity utilization. When transport distance is increased from 5 to 10 km, there is proportional-linear decrease in productivity. Decline continues at distance higher than 10 km (in this case 15 km), but this time it is not a linear relationship. Transport distance of about 15 km imposes the question of transport justification since the efficiency decreases significantly.

Energy parameters for the above mentioned distances are shown in Table 8. It can be seen that the coefficient of utilization of fuel in case of round bales oscillates from 16.20% to 18.20% and in case of square bales 18.90% to 20.73%. Technological energy goes from 26.78 to 80.46 MJ ha^{-1} in square bales case and 27.68 to 82.69 MJ ha^{-1} in case of round bales. Fuel consumption oscillates from 3.83 to 12.30 l ha^{-1}. The results suggest that with the increase in transport distance, there is a slight increase in fuel efficiency in the transport of both variants.

Fig. 3, 4 and 5 show that the achieved average fuel consumption in the collection with the Vicon baler and transport of straw within 5 km was 9.60 l ha^{-1}, the power consumption 21.54 kWh ha^{-1}, ie. 77.51 MJ ha^{-1} with the average percentage of fuel efficiency of 21.80%. The same technical solution in the case of increased transportation distance to 10 km has 48% higher fuel consumption, 35% higher energy consumption and 1.81% lower percentage of utilization of fuel in absolute terms. With the increase of transportation distance to 15 km, fuel consumption increases up to 17.30 l ha^{-1} (22%), technological energy consumption is 132.52 MJ ha^{-1} (26%), but this time there has been 2.7% increase in fuel efficiency.

Table 8: Energy consumption and percentage of fuel efficiency in transport.

Type of bale	E_{ha} [kWh ha^{-1}]	Q_{ha} [l ha^{-1}]	Energy technology [MJ ha^{-1}]	The total energy Fuel E_{ha}[MJ ha^{-1}]	Coefficient fuel efficiency[%]
Transport to 5 km					
Large square	7.44	3.83	26.78	141.55	18.91
Large round	7.70	4.60	27.68	170.02	16.26
Transport to 10 km					
Large square	15.38	7.66	53.53	283.11	18.90
Large round	14.87	9.20	55.10	340.03	16.20
Transport to 15 km					
Large square	22.35	10.50	80.46	388.08	20.73
Large round	22.97	12.30	82.69	454.61	18.18

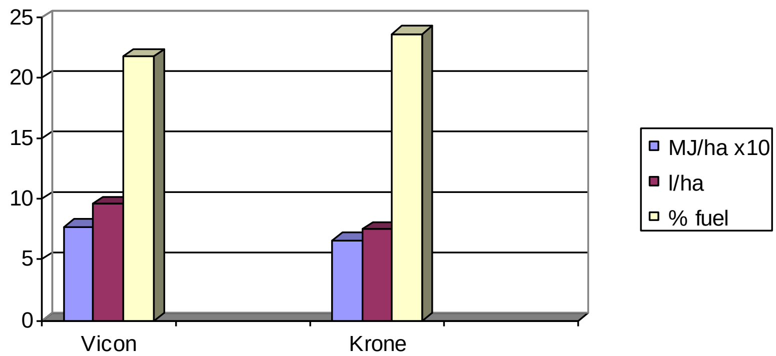

Fig.3: Energy consumption and percentage of fuel efficiency in the collection and transport (distance 5 km).

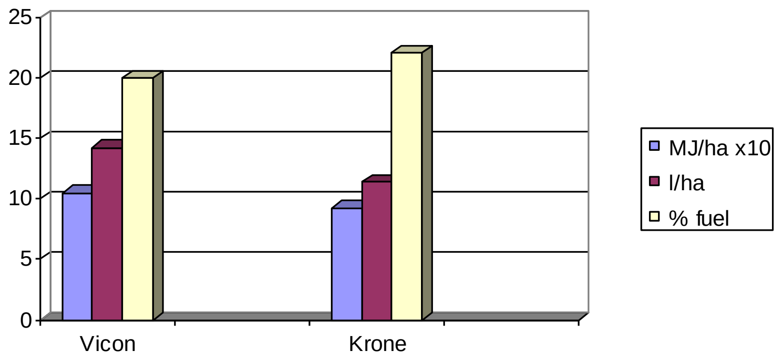

Fig.4: Energy consumption and percentage of fuel efficiency in the collection and transport (distance10 km).

This can be explained by the decreased fuel consumption per unit of transport length recorded with the increase in the transport section. When it comes to Krone press baler, fuel consumption on a shorter transportation distance is 7.54 l ha^{-1}, the power consumption is 18.34 kWh ha^{-1}, ie. 66.02 MJ ha^{-1}, and the percentage fuel efficiency is 23.69%. With the increase of transportation distance to 10 km, fuel consumption increases by 51% and energy by 40%, and the percentage of fuel efficiency is lower by 1.62% (Figure 6). When it comes to manipulation and transport of bales at 15 km distance fuel consumption increased by 25% compared with the 10 km the section, but fuel consumption per unit path length was 20% lower. Technological energy consumption is at a level of 119.70 MJ ha^{-1}, and fuel efficiency is 22.79% with the tendency to increase.

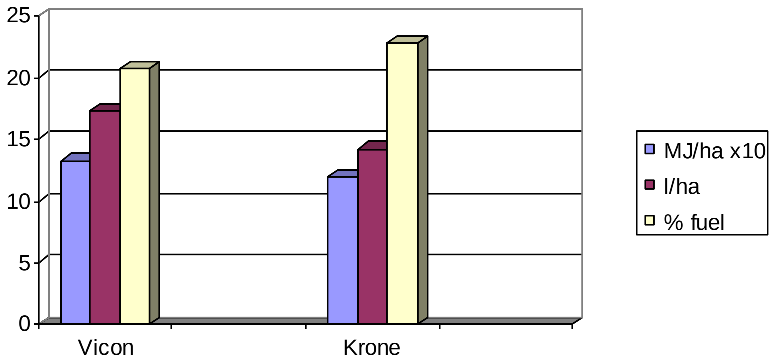

Fig. 5: Energy consumption and percentage of fuel efficiency in the collection and transport (distance 15 km).

When energy parameters of two different technical solutions are compared it is clear that the manipulation with the large square bales is more economical. Fuel consumption is about 20% lower if compared with the fuel needed for round bales. The energy consumption is 10-15% lower and fuel efficiency 8 - 10% higher. Knowing that the energy value of wheat straw, corn and soybeans is 12-15 MJ kg^{-1} and that the actual average yield of straw per hectare in PKB Corporation is around 2.5 t ha^{-1} it can be concluded that the total available amount of energy is around 30 GJ ha^{-1}. Based on the results it can be said that the energy cost and transport of materials of 297-570 MJ ha^{-1} is more than modest. Even so, when it comes to technical solutions for handling the residues more energetically efficient solutions should be purchased.

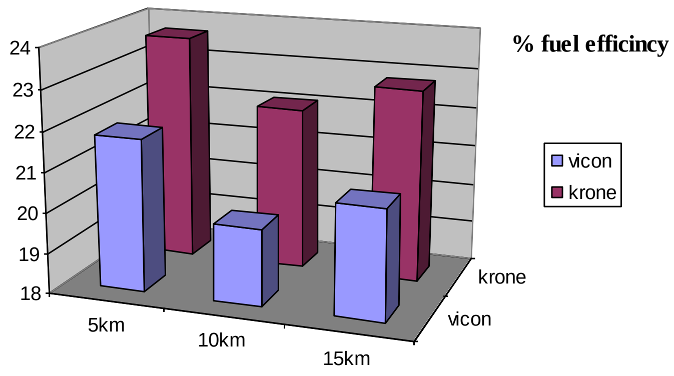

Fig. 6: The percentage of fuel efficiency on various transport distances.

3.1. Optimization of collection and transport of bales

Besides the obtained solutions, for both variants of collection and bales transport, a post-optimal analysis was made in order to determine the resources reserves and limitation parameters that are valid for the obtained solutions. Data used in the optimization system were obtained experimentally, and the choice of optimization criteria is a subjective assessment of the importance of the parameters measured during the experiment. Independent variables are 2 sets of distances to the warehouse in the model for the transport distance of 15 km. (A1 - Krone baler and bales transport, B1 - Vicon baler and bales transport). Technical coefficients are the values of certain parameters, which create a link between the independent variables and constraints. Their values are the result of research in the field, and in the model they are in the average. In both variants of the model required values are obtained with the fulfillment of given constraints. The nature of constraints allowed a wide interval of the lower and upper limit values of various parameters which indicate its validity and reliability.

To determine the minimum and maximum values of each variable, while other variables were fixed, final resolution limits were calculated (Table 9).

Table 9: The sensitivity coefficients in the constraints (B1).

Limitations	Set parameters	The resulting value	Acceptably	
			Increase	Decrease
E_{ha} [kWh ha^{-1}]	36.81	18.51	∞	18.30
Q_{ha} [l ha^{-1}]	17.3	7.95	∞	9.35
Total energy Fuel E_{ha}[MJ ha^{-1}]	639.41	288.12	∞	351.29
Productivity of transport [bale ha^{-1}]	27	67.34	40.34	∞
Productivity [ha h^{-1}]	1.2	3.02	1.82	∞
Coefficient fuel efficiency [%]	19.99	19.99	3.7	4.28

The results in Table 9 indicate significant differences since target value for each parameter is increased approximately 2 times so that energy has a value that is the same like with aggregate and transport B1 (from 130.62 to 132.91 MJ ha^{-1}).

Unlike the variant B1 in variant A1 limits show that the values are in the upper limit of the optimal solution which enables the achievement of targets. Thus, their reduction can go up to the point where they engaged systems A1 and B1 in ratio 0.54: 0.11. The problem is that in that case the fuel efficiency will be reduced to 19.54 and 18.87%.

4. CONCLUSIONS

Serbia belongs to the group of countries that are rich in crop residues. For this reason, it is quite reasonable to encourage a variety of measures not only for the production of energy from those renewable energy sources that are typical for Serbia, but also the development and production of equipment for their use.

The production of wheat, for every ton of grain gives a ton of straw or 0.43 tons of coal equivalent. In accordance with this relationship between the amount of biomass from crop residues and an equivalent amount of energy expressed in terms of coal in our country is about 1.290 million tons of coal equivalent from wheat straw.

The share of grain crops residue (wheat, rye, barley) in the total crop production is 50%, from corn 37% and from oil crops (sunflower, soybean, canola) about 13% [1].

In this paper two collecting systems for the crop residues are presented and analyzed. The obtained average number of bales per hectare is 8.9. When energy parameters are compared it is clear that the manipulation with the large square bales is more economical with the lower fuel and energy consumption and with the higher level of fuel efficiency.

In these conditions the average consumption of diesel fuel was 2 liters per bale that were in average 250-300 kg.

The results from the field show that the transport efficiency of the square bales was 20% higher if compared to the round bales manipulation.

The model defined in this paper could be extended by introducing the limitations associated with certain crops (the amount of straw, energy value of straw) and the economic benefits from the use of crop residues for heating. In this case, management would be facilitated by the choice of unit for collecting and transporting bales. The result of the model or its variations can help in improving the management that would be based on technical and economic indicators determining which system would be superior in terms of exploitation with a minimum of costs.

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Expert paper

COMPARISSON OF DRIFT REGULATIVES IN APPLICATION OF PLANT PROTECTION PRODUCTS IN SLOVENIA AND SOME EU COUNTRIES

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Abstract. *The paper presents different legislative concepts to limit negative side effects of plant protection product use and approaches for the continuous restriction on the conditions of their use. Very restrictive concepts are more or less acceptable to most of public who have no direct contact with agricultural production. The paper compares the systems of adjustable buffer zones for protection of surface waters and sensitive natural or urban areas against contamination with plant protection products, as in many EU countries is already the common practice, with the system of fixed buffer zones used in Slovenia and regulated by the Plant Protection Products Act and the Waters Act, and their sub-law regulations. In the areas, where the adjustable buffer zones are already established, there are more positive than negative experiences present, on the segment of monitoring of environmental parameters and also on the field of monitoring of the economic performance of agricultural producers. The alternative system that we intend to develop via the accomplishment of national research project would eliminate currently present difficulties detected at system of fixed buffer zones, which often discourage producers from investments into agriculture production, or even completely make the agricultural production unfeasible.*

Key words: *drift, reduction rate, drift-reducing nozzles, buffer zone*

1. INTRODUCTION

Increasingly intense agricultural production requires modern technical and technology solutions. This tendency can be maintained only by continuous improvement and development of modern technical solutions, as well as scientific achievements in the field of agricultural production systems engineering. The aim of this paper is broadening of the acquired knowledge in the field of mechanization of crop production, above all crop protection techniques against pests and diseases and possibilities of reduction of negative side effects of plant protection operations. Research and development activity is one of the key drives of modern world economy and agriculture, which is confirmed by data from three most developed countries in the world Germany, USA and Japan who invest 3-5% of their annual gross national income into research and development and extra 5% into continuous education of their personnel. Continuous improvement and development of agricultural engineering are the basics of modern agriculture.

Development and production of agricultural machines nowadays are mostly directed into:

- modifications and improvement of the existing agricultural machines, devices and equipment. This approach is usually predominant and characteristic for lower BDP countries and implies change of design of agricultural machines, application of new materials in their construction, improvements and innovations with the aim to reduce energy consumption and fulfilling ecological and ergonomic requirements;
- development of new technical and technological solutions for agricultural machines (e.g. exploitation of alternative fuels for powering of agricultural machinery, such as solar energy, electricity, bio oils etc.);
- development of information technology, program packages and modern technical solutions in accordance with principles of precision agriculture.

Application of plant protection products (PPP) is still an integral part of most conventional technologies of agricultural production. Methods for reduction of negative effects of PPP is a trend that increasingly draws attention, and conditions for their application are being limited constantly. Permanent control system and certification of machines for plant protection before placing on the market and periodically during the exploitation, as well as establishing of buffer zones in the areas of pesticides' application are typical examples of ecologically justified limitations directly influencing crop production. These limitations additionally increase crop production costs and endanger production profitability, while on the other hand they enable compliance with environmental standards of European Union prescribing considerable buffer zones in application of pesticides. Improvements of PPP application methods and machines have a huge impact on environment protection, as well as on the production of safe food. Integration of information technology into the exploitation of PPP application machines largely enables monitoring, control and certification of the equipment used. Significant reductions of use of PPP can be achieved by development of software for automatic guiding of operating parameters of application machines in relation to weather conditions, GPS positioning and plant structure and also of software for testing the performances of new or used machines.

2. TECHNICAL METHODS FOR DRIFT REDUCTION

The first measures to reduce drift of PPP are modern sophisticated devices for applying pesticides and efficient methods of their handling and testing. If we analyse drift reduction from the technical point of view, the drift can be reduced by better control of technical parameters using machines with built-in nozzle selection and configuration of operating parameters devices [1]. The main trends of improvement for field boom sprayers are related to the introduction of protective coverings of peripheral area of nozzles to the introduction of air assistance (sprayers with air support), thereby they are approaching to the design of orchard sprayers [2]. As a highly effective solution for drift reduction are sprayers with a single or double air curtain, where the spray is trapped in one or two air streams and drops cannot leave the narrow band within or between them [3]. Using of previously mentioned technical improvements at boom sprayers could reduce over 80.0% of a drift.

Installation of anti-drift nozzles into sprayers is basic technical solution. The main difference between the standard tip and anti-drift nozzle lies in the fact that the drift reducing nozzles at the same operating pressure produces greater droplets (more than 200 or 220 microns) and the proportion of small droplets is smaller than at the standard nozzles. Drift reducing nozzles are classified by level of drift reduction (eg 25%, 50%, 75%, 90%...) [4]. Also drift-reducing nozzles were developed, whose construction allows use of the “venturi effect” of pressure variation in a fluid and dynamic surface tension of the liquid before entering the nozzle orifice. This is called a venture nozzle with air intake vents (Summary antidrift air induction nozzles).

3. ORGANIZATIONAL TECHNICAL AND SPATIAL PLANNING APPROACHES

A lot of researches studied the possibility for reduction of drift by planting vegetation barriers [5],[6] in various European countries. Sometimes the measures of anti-wind, anti-flood control and anti-erosion control can be combined with the system for protection against the occurrence of pesticide drift (windbreak and anti-erosion stripes). Vegetation zones can be structured in natural vegetation or from purpose-planted plants that are durable and have the dense green wall for most of the year. Such areas of vegetation actually filter driftnet clouds that are realised during spraying of agricultural areas. They found out that the protective vegetation can lead to specific curvature of airflow that causes raise the hurdle drifting cloud and download at the drift distance of 50 to 100 m away of protective vegetation belts. Lazzaro et al. [7] demonstrated in their study that the use of hedges reduced drift from 82 to 97%. Hedges stand out as being a very good measure of drift reduction.

4. THE SYSTEM OF BUFFER ZONES

The pesticide drift governing legislation is primarily aimed at protecting surface and groundwater, and is closely related to the registration of PPP. Upon registration process for each of PPP the fixed minimum buffer zone is defined and put in the product label [2]. It has to be respected by users of products. The size of fixed zone is not related to the method or the conditions of PPP application.

The system of buffer zones was designed for spatial isolation of the treated areas of the areas that we want to protect from contamination by pesticide residues (water edge habitats, the environment...). Information on the minimum safety distance is an integral part of the data in the instructions on the use of products (label), and when using the product it must always be checked and respected. This is the minimum possible distance from the edge of the treated area to the edge of the area you want to protect, where the application of FFS is not performed. Buffer zone can be an integral part of the crop, but it can also be covered with natural vegetation, which has a filter effect. In some countries, the producers can afford large buffer zones up to 100 m or more from the edge of cropland. But in some cases, the growers are fighting for every inch of land. Thus, in the Netherlands there are regulations dealing with drift on a distance of 1 meter from the last row of the orchard. They have orchards only 2 meters away from the banks of water and if they have the suitable equipment they are allowed to apply pesticides close to water surfaces. Extensive buffer zones around fields in small perennial crops may have an adverse impact on production economics. The biggest problems are with narrow fields, alongside watercourses. In some PPP, for example, which have 20 m wide buffer zone, in some cases it happens that product cannot be used on core of filed and its use in the rest of the fields does not make sense [2].

We could say that in an average in case of environmentally less friendly pesticides basic approach is that drift should be at a distance of 20 m away from the edge of agricultural production area less than 0.1%. If the application reaches this goal, then for those living in the immediate vicinity of production sites, there should not be any cases of unacceptable drift load. Growers should be familiarised with detailed instructions on ways to implement the application of PPP to reach limit of drift at 20 m less than 0.1% [2].

Water bodies in our agrarian landscapes are located in the immediate vicinity of agricultural production sites; therefore there is significant potential for pesticide drift phenomena in to the aquatic environment. During the protocol of PPP registration, the minimum safe distance between the edges of cropland and water bodies has to be established (experiments or modelling). Regarding the buffer zones the Law on Water (BS, Ur carries out the categorization of water bodies/courses. L. RS. 67/2002), which distinguishes the water of first order (Drava, Dravinja, Meža, Mislinja, Paka, Sava, Savinja and Sotla...) and the water of second order (other waters). The use of plant protection products is prohibited on the coastal area of first order water bodies at the distance of 15 m from the border bank line and at the distance of 5 m from the border bank line of second order water bodies. However, if the asset is required on the label of a wider buffer zone, for example 30 meters it has to be taken into account by user of PPP. In Austria, the use of PPP is prohibited in the vicinity of water bodies with the floor width of 10 m from the border bank line in case of first order water bodies (Rhine, Lippe, Sieg...) and 5 m from the border bank line of second order water bodies (all the other surface water bodies).

Slovenia currently has a system of fixed buffer zones (20 to 100 m), which are always the same, regardless of the circumstances of the application of PPP and irrespective of the type and level of development of technical devices for application of PPP. Even if the producer has the most modern equipment for the application of PPP that enables 95% reduction in drift, this does not affect the possibility of using PPP preparations. In many EU countries they have decided that farmers who use appropriate equipment shorter distance of the buffer zones will be allowed. So they have introduced variable (flexible) buffer zones in practice. The system is incorporated in the instructions for use of PPP (label). The actual implementation of the system varies from country to country. In England they have the system called LERAP (Local Environmental Risk Assessment for

Pesticides) [8] and in Germany they also have system to declare the drift rate reduction for each device.

In Germany they had a similar system as in England [9] since 2000, but the producers seemed too see it to complicated so they simplify it. Today in Germany and Austria the instructions for use of PPP specify the scope of a possible reduction in the buffer zone, if the operator has the equipment, which is officially declared that it has the ability to reduce drift to a certain proportion. The decision is on the producer of crop. If producer does not have the equipment declared to reduce drift, the producer must comply with the maximum buffer zone, but if, for example, his equipment is officially declared to reduce drift for 75% the buffer zone can be reduced at least for 30%. For the application of certain PPP, the producer of crop must have at his disposal appropriate equipment; otherwise the application is not possible.

5. Legislation in Slovenia

The Republic of Slovenia adapts all existing and new legislation put in force by EU. The main purpose of adaptation is to establish a uniform system for health care of plants and for identification and protection of areas under concern. Plant Protection Products Act (Act on PPP) directs that it is not allowed to use pesticides in a manner that would cause contamination of residential, commercial and similar facilities, which are occupied by people and animals, and could cause contamination of adjacent lands and waters [10].

According to the rules governing the duties of the user of PPP, the user must take into account the limitations of the specific crop production locations for the protection of groundwater, as shown in the label and instructions for use or non-use of certain pesticides. And then he has to comply with the prohibitions and restrictions on the use of pesticides in certain areas in accordance with the regulations governing water protection. The user must ensure that the PPP does not come into direct contact with people and to avoid drift to:

- watercourses, lakes and other water,
- ground water,
- the facilities for the supply of drinking water,
- neighboring crops, land and storage of agricultural products,
- the storage facilities and processing plants, facilities for breeding and care of animals if such use that may endanger the health of humans and animals.

In the registration process, the PPP is assessed in terms of risk to the environment (non-living and living world). The use of PPPs may not represent an unacceptable risk to non-target organisms (birds, mammals, fish, insects...) and non-target plants. The European Union and Slovenia protects its precious water resources from over-exploitation and pollution with the full implementation of EU adopted legislation. The provisions of the framework of Water Directive have been fully transposed into Slovenian legislation with the Act on Waters.

6. Legislation in the EU (Germany, Austria)

One of the main problems related to PPP in the EU Member States is the pollution of surface and ground water, especially water resources that are intended for human consumption. We have to say that legislative in this field in Europe is very well regulated. At the beginning there was Council Directive 91/414/EEC concerning the placing of plant protection products on the market. This Directive concerns the authorization of PPPs and provides the ability to restrict permission for certain uses of PPP and then it sets out specific requirements for the use, for example, measures to reduce the risks related to water contamination. So it lays down the rules governing the placing of PPPs on the market and the active substances contained in those products.

This directive follows the Regulation 1107/2009 concerning the placing of PPP on the market and repeals Council Directives 79/117/EEC (on the prohibition of the trade and use of PPPs that are containing certain active substances) and Directive 91/414/EEC. This Regulation lays down rules for:

- the registration of pesticides in commercial form,
- their placing on the market,
- use and control in the community,
- the approval of active substances; guards or synergist contained in the plant protection products or consist of,
- rules for adjuvants and additives.

The purpose of this Regulation is to ensure a high level of protection of human and animal health and the environment and to improve the functioning of the internal market by harmonizing the rules concerning the placing of plant protection products on the market, while improving agricultural production.

7. Water Framework Directive

The European Parliament and the Council 2000/60/EC adopted the Water Framework Directive (WFD). The purpose of this Directive is to establish a framework for the protection of inland and surface water, coastal waters and groundwater. It talks about:

- coordination of administrative arrangements within river basin environmental objectives,
- characteristics of the river basin district,
- it reviews the impact of human activity on the environment,
- the economic analysis of water use.

In this directive it is also described the register of protected areas. Furthermore it describes the water used for the abstraction of drinking water, and strategies for the prevention of water pollution, groundwater, defines surface waters, ground waters and protected areas.

The Water Framework Directive is not confined to public-private partnership, but the overall volume of water protection. Other provisions in similar areas have been defined previously:

- Directive 75/440/EEC on the required quality of surface water intended for the abstraction of drinking water in the Member States. This Directive regulates matters of the quality requirements that has be met by surface fresh water used or intended for use in the abstraction of drinking water after appropriate treatment. This Directive does not apply to groundwater, brackish water and water intended to replenish aquifers. For the purposes of this Directive, all surface waters that are intended for human consumption and supplied by distribution networks for public use shall be considered as drinking water. It also talks about the definition of the standard methods of treatment for transforming surface water of categories A1, A2 and A3 in the water and on the characteristics of surface water intended for the abstraction of drinking water.

- Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment. This Directive applies to inland surface waters, territorial waters, internal coastal waters and groundwater.
- Council Directive 80/68/EEC on the protection of ground waters from pollution that is caused by certain dangerous substances. The purpose of this Directive is to prevent pollution of groundwater with dangerous substances. It also has attached Annex of families and groups of hazardous substances.

8. Legislation on plant protection and reduction of drift in Austria

On the February 15th 2011, the new law was published in Austrian Official Gazette on PPP, which fully came into effect on 14 June 2011. The new law serves the implementation of Directive 2009/128/EC establishing a framework for Community action for the sustainable use of pesticides and the implementation of the European Communities 1107/2009. Details of implementing legislation will be put in use on the provincial level (nine provinces - each will have its own legislation). It describe the fallowing details:

- the required basic and further training of users and sellers of PPP
- testing of application equipment,
- public information,
- the use and cleaning of application equipment,
- restrictions and prohibitions of pesticides use,
- reducing the risk of accumulation of PPP development and implementation of integrated indicators and control the use of pesticides.

9. Drift regulation model in Germany

In Germany the granting of licenses (authorizations), for placing plant protection products on the market is closely linked with the previous determination of the buffer zones for application nearby water sources, as well as the characteristics of application equipment associated with the potential to cause drift. In 1993, they began to establish a register of equipment that is declared as the equipment to reduce drift. Before placing any new PPP application device (and accessories) on the marked, they have to be tested for its drift characteristics. When testing a new device for the characteristics of drift, the values obtained in measurements of drift in the standard protocols, are compared with the standard reference values specific to the German market, which are given in the registry data, called "basic drift values". New devices are then assigned to the appropriate class of drift reduction (Briefings drift Reducing class, Ger. Abdriftminderungsklasse). Basic classes in the registry were 50%, 75% and 95% drift reduction class. For the classification of devices in the same class they must conduct experiments on field tests or/and wind tunnel. Register of devices and data to include them in the individual classes of drift reduction are then presented in the Federal Law Gazette (German Bundesanzeiger). The data from this register is also used in the registration of new plant protection products to determine allowed deviations from the prescribed distances for seat fix buffer zones. The size of buffer zone for the individual PPP is determined by the rate of reduction of drift by the equipment intended to be used for its application. This means that the same PPP is allowed to be applied at a different distances from the source of water, depending on the type of application equipment. In some cases, new products for plant protection cannot be registered for application by standard application equipment, but could only be registered for use by sophisticated equipment assisted with the application software, and which is officially declared that provides a specified high degree of drift reduction. Such approach to the regulation of spray drift by following the strict environmental terms causes that old machines could not be used any more [11].

In Germany, the entire territory is mapped according to the sensitivity of different areas for drift. GPS-guided device for application of PPP during the work in the field monitors the position of device in relation to the sensitive areas, and when approaching sensitive are, it warns the operator that the device is close to a special zone where the zone undergoes to certain restrictions or device is moving towards such a zone. Device automatically changes the operating parameters and the type of active nozzles.

To reduce the width of the buffer zone they have created a list of devices and equipment that reduces drift. Depending on equipment installations they are divided into classes drift reduction: 50/75/90%. Julius Kühn-Institut (JKI), Federal Research Center for cultivated plants, published a list of approved devices to reduce drift. Continuous updates are available from 10th of February 2011. We can always find list of drift reducing nozzles with drift reduction classes (50/75/90%) for agriculture on the websites of JKI. User of PPP can always check the status of his equipment and adopts the size of buffer zone according to the combination of type of equipment, size of fixed zone stated in label and rate of reduction of fixed zone stated in the label.

10. DRIFT REGULATION MODEL IN AUSTRIA

To reduce the width of the fixed buffer zones also in Austria they have created a list of devices and equipment that reduces drift. Approach is similar to the German one. Depending on equipment installations they are divided into fallowing classes of drift reduction: 50/75/90/95% (with specific conditions, such as the anti-hail nets in orchards). Federal Ministry of Agriculture, Forestry, Environment and Water Management published list of approved equipment and devices to reduce drift. List of equipment to reduce drift is presented in Annex 2 List of drift reducing nozzles with drift reduction classes (50/75/90%) for Agriculture, which entered into force on 1st of February 2012 and it is published on the website of the Ministry.

11. CONCLUSIONS

The results of the research work in the frame of national project show that the transformation of regulation of drift from system with fix buffer zones to the variable buffer zones has potential to be implemented in Slovenia. The reduction of currently regulated surface waters buffer zones in PPP use can be achieved, thus leading to the increasing of agricultural areas available for efficient food production, thereby increasing food security through stable production of safe, quality food and consumer access. In the frame of the national project jointed strengths of the administrative staff of the Ministry of Agriculture and of Environment and researchers who are experts in the areas of the environmental and agricultural legislation, drift modelling of PPP, spatial analysis and modelling of PPP ecological influence on the environment. The main objective of the project group is to introduce alternative system of adjustable buffer zones (surface waters, application of PPP in areas near urban settlements) in PPP use in Slovenia. To achieve the main objective of the project a detailed review of legislation approaches in other European countries (e.g. Austria and Germany) is necessary. The transformation of their corresponding data on possible reduction of buffer zones in pesticide use and different types of application equipment should be easily executed in national dossier on GAP for specific PPP. Environmental standards that are followed in authorization procedure of PPP and the determination of use of adjustable buffer zones as implemented in Austria or Germany are good enough for their implementation in Slovenia. Furthermore, the project proposes the establishment of a permanent on-line register of application equipment for PPP application with different categories of drift, the establishment of new sub-law regulation about placement of new equipment in to register of anti-drift equipment and the suggestion to prepare necessary expert groundwork for future legislative link between the registry and the authorization procedure of PPP and between the guidelines for PPP use. In the final stage of the project, additional recommendations will be developed on how to introduce corresponding certificates, which will designate the category of application equipment regarding the level of reducing the drift, into the system of certification and inspection of application equipment. All proposed project activities are in accordance with the development and implementation of national strategies for sustainable use of pesticides, which is part of the activities of Directive on Sustainable Use of Pesticides.

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First communication

NEW EU TYPE APPROVAL FRAMEWORK REGULATION FOR AGRICULTURAL AND FORESTRY VEHICLES

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Abstract. *In the Official Journal No. 167 from 2013 the new Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles has been published. This Regulation is a framework legislation that covers all technical requirements for agricultural and forestry vehicles before being put on the market. It will repeal the existing framework Directive 2003/37/EC and also 23 separate Directives on 1 January 2016. The layout, the structure and main requirements are aligned with the framework legislation for motor vehicles with four or more wheels. The European Commission that prepared this regulation followed recommendations from the Competitive Automotive Regulatory System for the 21st century (CARS 21) report and therefore simplify the current whole vehicle type-approval regulatory framework. This Regulation is followed by seven delegated acts and one implementing act. This paper describes all chapters of this new regulation and point out all important and new prescriptions.*

Key words: *EU legislation, agricultural vehicles, forestry vehicles, approval*

1. INTRODUCTION

On 2 March this year the new Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles was published [1]. This is the so called “mother regulation” that regulate all technical requirements for agricultural and forestry vehicles before putting on the market and is harmonized in all Member States of the European Union. The regulation entered into force the twentieth day after its publication, but it shall apply from 1 January 2016.

2. THE PREPARATORY WORK

Before this Regulation for the framework legislation the "Directive 2003/37/EC of the European Parliament and of the Council of 26 May 2003 on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EEC" had been in use [2]. Because of this type of the legal act all Member States had to transpose it into their national legislation. In the Republic of Slovenia we transpose this Directive with the "Rules on approval of agricultural and forestry tractors" [3].

In the summer of 2010 the European Commission prepared the proposal of new framework legislation for the regulating the agricultural and forestry vehicles. For the legal instrument they used the Regulation instead of Directive. The background for this decision was a large impact assessment prepared in years 2008 and 2009 that resulted in a better way of organizing this area. The proposal has been prepared also in accordance with recommendations of "Competitive Automotive Regulatory System for the 21st century" (CARS 21) [4].

The goal of the new Regulation was to ensure in the field of agricultural and forestry vehicles the high level of traffic safety, work safety and environment protection. Based on these they decided that technical requirements and environmental standards for approval of vehicles their systems, components and separate technical units had to be harmonized.

The European Commission has justified this with reference to the impact assessment that showed that the present system in the field of agricultural and forestry vehicles is too complicated for vehicle producers and also for approval authorities. Furthermore they found out that all Member States have to transpose all directives into their national legislations, which creates a lot of additional work for them without added value. And, with this proposal they had an idea to improve the work of the internal market of the European Union in order to bring easier movement of agricultural and forestry vehicles between Member States.

The text of the Regulation has had to undergo the public consultation procedure and also a lot of consultations on various working sessions in the European Commission, European Council and European Parliament. Therefore the text has been changed during this procedure and the final compromise was reached at the end of year 2012.

3. WHAT IS NEW?

3.1. In general

The first thing is the new form of the legal act. This is a Regulation instead of Directive that means that there is no need to transpose it into the national legislation. The Regulation is in force in all Member States on the same day. That means that the National authorities have significantly less work than with Directives, there is no possibility for mistakes in transposing and also there is no need for the European Commission to check the proper transpositions in Member States.

Technically all requirements in the Regulation are on the same level as they are now.

The Regulation will be followed by some implementing and delegated acts that represent the new approach in the legislation, so called “split level approach”. The number of these acts will be lower than at present. At the moment under the framework Directive there are 24 separate Directives. It is foreseen that only 8 acts will follow this Regulation:

- delegated act on functional safety of vehicles,
- delegated act on occupational safety,
- delegated act on environmental performance,
- delegated act on braking,
- delegated act on testing,
- delegated act on access to repair and maintenance information,
- delegated act on technical services,
- implementing act on harmonized administrative requirements.

3.2. An overview of the Regulation

3.2.1. Chapter I: Subject matter, scope and definitions

There is a statement in the Article 1 that this Regulation establishes the administrative and technical requirements for the type-approval of all new vehicles, systems, components and separate technical units. However this Regulation is not applicable for the approval of individual vehicles but, essentially, it determines the requirements on market surveillance of vehicles, systems, components and separate technical units and also of the equipment.

This Regulation is applicable on wheel tractors (category T), track-laying tractors (category C), trailers (category R) and interchangeable towed equipment (category S). It is not applicable on interchangeable machines that are fully raised from the ground or that cannot articulate around the vertical axis when the vehicle to which it is attached is in use on a road. The manufacturer may choose between procedures from this Regulation or national requirements for trailers, interchangeable towed equipment, track-laying tractors and for special purpose wheeled tractors (category T4.1 and T4.2).

The basic classification of agricultural and forestry vehicles is not changed. It consists of: tractors (category T for wheeled and C for track-laying tractors), trailers (category R) and interchangeable towed equipment (category S). There are changes in subcategories. For category T we have now subcategories T1, T2, T3, T4.1, T4.2 and T4.3 (the same at category C) with the index “a” if they have the maximum design speed below of equal to 40 km h^{-1} or “b” if they have the maximum design speed more than 40 km h^{-1}. This is the same categorization as was in use for trailers and interchangeable towed equipment.

3.2.2. Chapter II: General obligations

The Chapter II of this Regulation regulate the obligations of Member States regarding the designation of approval authorities and surveillance authorities as well as the method of market regulation, obligations of approval authorities and market surveillance measures. Market surveillance authorities will perform their tasks at manufacturers of agricultural and forestry vehicles and equipment, their representatives, importers and distributers. In articles that follow we could find obligations of manufacturers, representatives, importers and distributers especially for products that are not in conformity or that present a serious risk. For the last mentioned there are obligations for immediate actions concerning the corrective measures for withdraw or recall of such products from the market.

3.2.3. Chapter III: Substantive requirements

This Chapter is probably the most important part of this Regulation because it defines technical requirements for approval of agricultural and forestry vehicles. It was mentioned before that this requirements are on the same level as they are already now. These requirements are divided into:

- Requirements for the functional safety of vehicles where we could find vehicle structure integrity, vehicle lighting systems, audiable warning devices, vehicle occupant protection, masses and dimensions, etc.
- Requirements for occupational safety where we could find ROPS, FOPS, OPS, driving seat, safety belts, batteries, etc.
- Requirements for environmental performance where we could find pollutant emissions and external sound level. For the limit values for pollutant emissions the regulations has the reference to the Directive 97/68/EC that regulate the emissions from mobile machinery. In this article we could find limit values for external sound levels. There are only two limit values; that for tractors with an unladen mass in running order of more than 1500 kg (89 dB(A)) and for those that the mass is not more than 1500 kg (85 dB(A)).

3.2.4. Chapter IV: EU type-approval procedures

The Chapter IV of this Regulation give to the manufacturer different procedures to obtain the whole vehicle type-approval for the agricultural and forestry vehicle they produce. The manufacturer has now possibility to choose step-by-step, single-step or mixed type-approval. Requirements regarding the documentation are very similar to recent requirements. The European Commission has to prepare templates for information documents by 31 December 2014.

3.2.5. Chapter V: Conduct of EU type-approval procedures

The content of this Chapter is very similar to the current situation laid down in the framework Directive. We find here the EU type-approval certificate, test requirements and provisions regarding the conformity of production. The European Commission has to prepare firstly, implementing acts regarding the numbering of implementing acts, the content of EU type-approval certificates, the templates of test reports and the list of requirements of acts by 31 December 2014. By the same date the European Commission has to prepare also the first delegated acts concerning the detailed arrangements for the conformity of production.

3.2.6. Chapter VI: Amendments to EU type-approval procedures

Also the content of this Chapter is very similar to the content of recent framework Directive. It regulates revisions and extensions of EU type-approvals, issuing of amendments and notifying approval authorities in other Member States.

3.2.7. Chapter VII: Validity of EU type-approval

In this very short Chapter we can find in which situations the EU type-approval become invalid. The content is very similar to the current.

3.2.8. Chapter VIII: Certificate of conformity and markings

This Chapter consists of the prescriptions regarding the vehicle certificate of conformity and on statutory plate that shall affix to each vehicle manufactured in conformity with the approved type. The content is also in this Chapter very similar to the current but the European Commission has to prepare first implementing acts regarding templates of Certificates of conformity by 31 December 2014.

3.2.9. Chapter IX: Exemptions for new technologies or new concepts

The content of this Chapter is completely new in this field and it regulates how to accept new technologies and the procedure to authorisation by European Commission. For every new technology the authorisation from European Commission has to be given by means of an implementing act. There is also an article that regulates the procedure for the European Commission to adapt delegated and implemented acts with new technologies.

3.2.10. Chapter X: Vehicles produced in small series

This Chapter regulates for the possibility of a manufacturer applying for the national type-approval of small series but in number of vehicles prescribed in the Annex II of this Regulation. For the national approval authorities there is a possibility that could waive one or more of the provisions listed in Annex I could be waived if they have reasonable grounds but they have to specify the alternative requirements. The validity of this national type-approval is restricted to the territory of the Member State whose approval authority granted the approval. Approval authorities in other Member States could decide if they will accept such type-approval or not.

3.2.11. Chapter XI: Making available on the market, registration or entry into service

In this Chapter there are prescriptions separated in articles for vehicles build in large series, in small series and for components and separate technical units. All vehicles produced in large series have to be followed with the valid certificates of conformity. The number of vehicles produced in end-of-series shall not exceed 10% of the number of vehicles registered in the two preceding years or 20 vehicles per Member State, whichever is higher.

3.2.12. Chapter XII: Safeguard clauses

This Chapter prescribes a harmonised procedure for all Member States in how to handle vehicles, systems, components or separate technical units if they present a serious risk to the health or safety of persons or to other aspects of the protection of public interest. There are articles separated for vehicles, components and separate technical units. There is also an article that describes the recall procedure for vehicles, systems, components and separate technical units if they present a serious risk to safety, public health or environmental protection even if they are approved according to this Regulation. The recall procedure is in accordance with the Regulation (EC) No. 765/2008, that prescribes the requirements for the accreditation and market surveillance of these products.

3.2.13. Chapter XIII: International regulations

In this Chapter we could find stipulations about the recognition of UNECE Regulations that the European Commission perform with the acceptance of the relevant delegated act. The same procedure is also for acceptance of the OECD technical reports.

3.2.14. Chapter XIV: Provision of technical information

The Chapter XIV of this Regulation regulate the obligations of manufacturers to make available to users all relevant information and necessary instructions any special conditions or restrictions linked to the use of a vehicle, system, component or a separate technical unit. It is also prescribed the exchange of information between the vehicle manufacturer and the manufacturer of components or separate technical units.

3.2.15. Chapter XV: Access to repair and maintenance information

With this Chapter the Regulation establishes the obligations of manufacturers providing all relevant information for vehicle repair and maintenance to authorised dealers, repairers and independent operators. These prescriptions are similar to those in acts for passenger cars and goods vehicles. The Regulation contains also the list of information that has to be available (service handbooks, technical manuals, wiring diagrams etc.). It is a possibility given to manufacturers that they may charge reasonable and proportionate fees for access to this information.

3.2.16. Chapter XVI: Designation and notification of technical services

This Chapter contains requirements for technical services that are designated by the approval authorities as testing laboratory for performing tests or as conformity assessment body performing initial assessment and other test or checks. There are also articles regarding the designation of the technical service into one of the four categories, regarding the in-house technical services of the manufacturer and regarding the assessment of the skills of the technical services. In this Chapter we can find also the procedures for notifications of technical services to the European Commission and of reporting about changes as well as obligations of technical services about their work and reporting.

3.2.17. Chapter XVII: Implementing acts and delegated acts

In this Chapter we could find information which implementing acts will be adopted by the European Commission for the full implementation of this Regulation. It also states that the European Commission will be assisted by the "Technical Committee – Agricultural Vehicles".

3.2.18. Chapter XVIII: Final provisions

In the last Chapter of this Regulation we find penalties for the situations when the obligations of this Regulation have been violated. Furthermore there are transitional provisions, dates for sending reports about the use of approval procedures and time-limits for reports on individual approvals for vehicles per year before year 2016 and on national rules for those procedures. There is an article regarding the repealing of directives and about the date of entering into force. This Regulation entered into force on twentieth day following its publication in the Official Journal of the European Union and it shall apply from 1 January 2016.

3.2.19. Annex I: List of requirements for the purposes of vehicle EU type-approval

This Annex is probably the most important part of this Regulation because there are in the table listed all technical requirements for EU type-approval for different categories of agriculture and forestry vehicles. In the table we find for each subject a reference to a relevant article in this Regulation and a reference to a relevant regulatory act, EU or UNECE Regulation or OECD Codes.

3.2.20. Annex II: Limits for small series

This Annex set limits of tractors categories T and C produced in small series made available on the market, registered or entered into service per year in each Member State. For tractors category T this limit is set at 150 and for tractors category C at 50 units.

3.2.21. Annex III: Correlation table

In this Annex is shown the transposing of articles from the recent framework Directive (2003/37/EC) to this Regulation.

4. CONCLUSIONS

This Regulation has introduced many new features to the field of agriculture and forestry vehicles. These are in the approval procedures and also in other relevant aspects of the work especially in market surveillance. In the beginning of the work this will bring quite a lot of challenges for manufacturers and also to approval authorities and technical services. Fortunately there is still a long transitional period before the start of the application of this Regulation. And in this period we expect to have enough time for a preparation.

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Scientific review paper

THE CONTRIBUTION OF AGRICULTURAL MACHINERY TO SUSTAINABLE AGRICULTURE

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Abstract. *Sustainability plays an increasingly important role in the technical development of agriculture. Technical development is the framework of complex development activities in agriculture and it is similar to sustainability as it covers and integrates biological, chemical, technical and human factors. Intelligent production methods which have been developed in recent years mean great steps into the direction of sustainability. These up-to-date farming methods can be grouped under the umbrella of "precision farming". Machinery development plays a determining role among the complex innovation process. This paper presents the new technological solutions which are used in agricultural production. The economic background of agricultural machinery supply and the importance of training and education are also discussed.*

Key words: *sustainability, intelligent production methods, machine supply*

1. INTRODUCTION

Sustainability is associated with three major aspects: economy, ecology and social affairs. When sustainability is demanded from agriculture people and experts focus on both the environment and society. The main demand from the society is for the satisfaction of the needs of a rapidly growing population regarding good quality food and energy in a long period of time. Today it is not possible to intensify agricultural production through the significant expansion of cultivated area. Our task is to intensify agricultural production on the existing areas causing as little environmental degradation as possible [1].

The quantity and quality of agricultural production are in close connection with innovation and technical development. The different elements of technical development are not only parts of the used resources, but they form a special framework for the efficient and internationally competitive production [2]. The appearance of intelligent production methods, the „precision farming" is a great step into the direction of sustainable agriculture. The main objectives of our paper are the following:

- to summarize the background of intelligent agricultural methods, focusing on the technical, biological and economic aspects,
- to give a brief overview about the up-to-date technical and technological solutions concerning some problems and the future development of precision farming,
- to show the economic background of the agricultural machinery supply using some international examples,
- to prove the importance of vocational training and education.

2. MATERIAL AND METHODS

Concerning the development of the automated technological solutions partly based on the earlier publications of Faust [3] I focused on the three lines of the automated systems as it is shown on Figure 1. The harmonized operation of the three available systems (communication networks, offices and machines) can establish the framework of precision farming. The total technological process of precision plant production should contain several elements [4] as it is summarized in Figure 2.

I have studied the Hungarian and international situation of the agricultural machinery supply. Most of the data mentioned in this paper were gathered from the economic report of VDMA and Eurostat [1, 5] .

3. RESULTS AND DISCUSSION

3.1. Intelligent production methods

Nowadays, most of the agricultural tractors and harvesting machines bought by the farmers are equipped with modern technology. These machines are well developed mobile mechatronics systems. It means that the complicated functions are performed by the harmonized operation of hydraulic, pneumatic, electronic, optic and informatics devices. The development of automation has three strata, which means that automation appears not only in the machines, but in the offices and on the field i.e. all over the world Fig. 1. It means that

- the microcontroller data-communication system (CAN BUS) is part of the modern tractors and harvesters,
- in a modern office we can find the different packages of computer aided engineering and business management software and
- the application of internet, GPS and GIS is natural part of our everyday life.

The long-term objective of this automation process is the better combination of information and integration of different processes. One of the most important opportunities in the technical development of agriculture is the combination of the three areas for particular purposes. Precision farming is a good example [3].

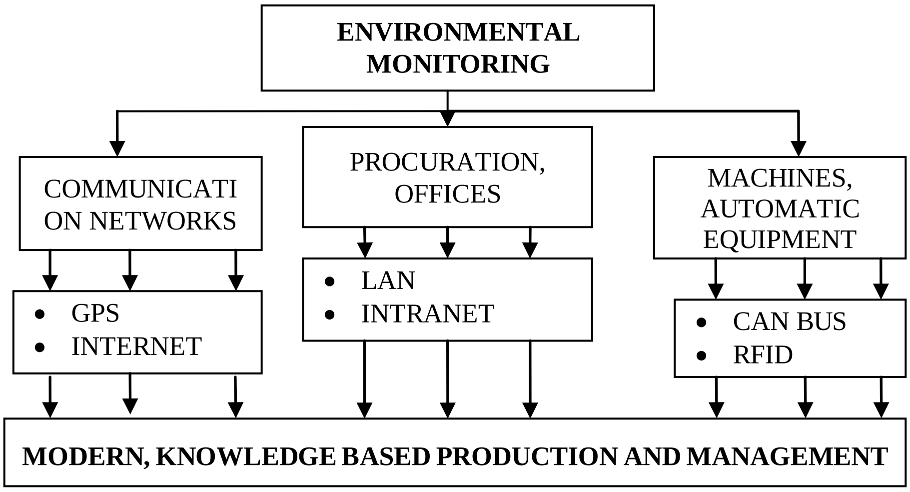

Fig. 1: The three strata of automation (based on [3]).

One of the most important features of the intelligent production methods is the automatic capture and documentation of data. During production, the machine automatically captures data that can be of relevance for the future cultivation of the area using sensorics or video technology. Such data can be the exact application amount of fertilizers, plant protection products or seeds, the constituents of plants or soil, or the weight and moisture of harvested products. Through satellite navigation, it is possible to record the exact location in which the data were captured [6]. In addition, machine data such as the distance driven, the lane used, labor time, fuel consumption or speed can also be recorded automatically. Immediately after capture, all information is automatically transmitted to the farm computer. The data collected this way offer a higher degree of transparency and can be the basis for an automated precision farming.

The entire area for agricultural cultivation is divided into partial areas and mapped according to the different local conditions of soil and plants. It can be done either using existing data, through real-time data capture or through remote sensing. The agricultural machines programmed according the data can cultivate each partial area according to the special needs. It means that fertilizer spreaders, sowing-machines and sprayers can automatically use the exact resources needed for each partial area, in exactly the amount required for maximum output. This is economical for the farm, and also sensible from a sustainability viewpoint. For this way a maximum yield is achieved on limited areas, without additional pollution of the environment by excess amounts of plant protection products or fertilizers.

Also important features of the intelligent production methods are the parallel guidance systems which are important elements in precision farming. Steering systems are the simplest version. By means of satellite navigation, they show the operator the best lane on the display, without intervening in steering. In contrast, steering assistance or automatic steering systems detect the lane with a degree of accuracy of up to two centimeters by means of satellite navigation, sensors and/or video technology and actively take over steering. Turning at the end of the field, so-called headland management can also be fully automated. Through exact navigation, overlapping and missed spots can be avoided, reducing fuel consumption, plant protection products, fertilizers, and maximizing yields [1].

This modern and rapidly developing farming method is suitable for large-scale agricultural enterprises. For the efficient application of the listed intelligent production methods the total process, all of the important elements should be applied Fig. 2.

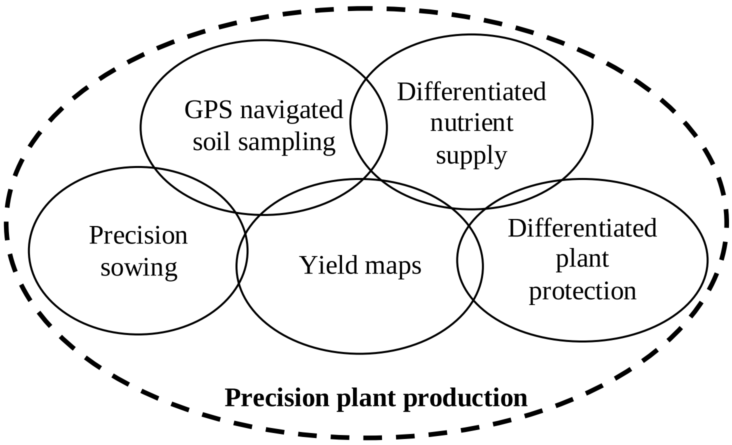

Fig. 2: The important elements of precision farming (based on [4]).

The long-term objective of precision farming is to achieve a perfectly interlinked and automated process chain. The first successful attempts have already been made, especially in the production of potatoes and sugar beet. However, there are still some obstacles to overcome on the way to a closed overall process. The compatibility of machines and equipment from different manufacturers still poses a challenge. The ISOBUS standard defines the physical features of the network, plugs, wiring and data formats so that devices can exchange data with each other. More than 50% of the modern tractors and self-propelled agricultural machines are already equipped with ISOBUS systems – within the high-performance spectrum almost 100% are.

Concerning the future development of the intelligent production methods and technical solutions there is still scope for further improvement of data capture and analysis on the machines. The machine sensors could be developed further to enable the assessment of yet more plant and soil constituents than currently possible. This would allow an even more precise use of plant protection products and fertilizers. External information such as climate data could also be included in the data analysis. The capture of data should focus on providing a clear and sensible basis for decision-making. Based on our field experiences that feature has been criticized by some users in the past. Up to now, some farmers have felt that, while they have access to a large quantity of collected data, they do not receive concrete aid for further steps.

3.2. Agricultural machinery supply

Agricultural machines and equipment are important and expensive resources. It is always good news for the agricultural machinery industry that farmers achieve good earnings with the agricultural products. The agricultural income in the European Union increased in 2010 and in 2011 as it is shown on Fig. 3. In the year 2011 the corresponding index per agricultural worker in the EU was 9% higher than the average of the five previous years. Even in comparison to the preceding year, when the level was already good, there was an increase of 7%. Only in a few countries of the EU did earnings fall [5].

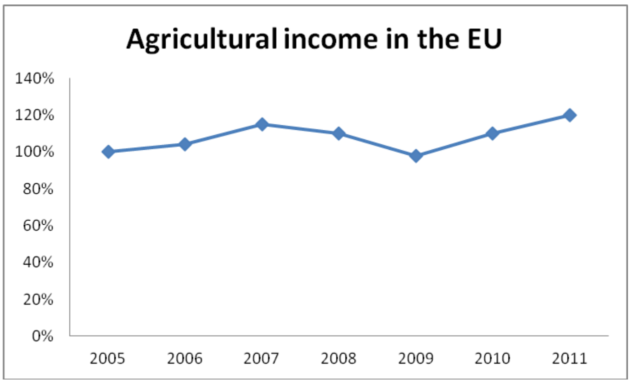

Fig. 3: The increase of agricultural income in the EU [5].

The worldwide production volume of agricultural machinery grew up to €80 billion in 2011 Fig. 4. It was an increase of 18% compared to the previous year. After a decrease in 2009, the production of agricultural machinery recovered quickly. This was an increase of 18% compared to the previous year. The European Union is the largest production location in terms of turnover value. European production stands for technology leadership based on the impulses from the domestic market. There is a worldwide demand for any products developed by European engineers. However, its share has decreased continuously in the last few years and it is currently about one third. The main reason for this is the growth of the production in China. Some years ago, it did not even represent 10% of the worldwide volume but it is currently between 15 and 20%. China was one of the regions with above-average growth in turnover and exports rose by 20% in 2011[1].

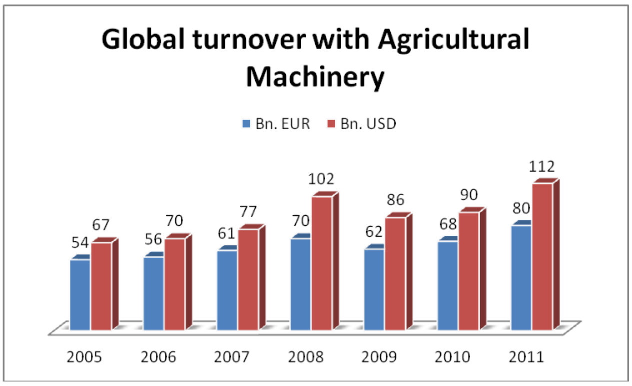

Fig. 4: The increase of global turnover of agricultural machinery [1].

For the second running year, growth was very strong in Turkey. More than 60,000 units of tractors were manufactured. The impulses from the domestic market and demand from abroad helped Turkish companies to achieve this enormous number Fig. 5. Turkey will not be able to maintain its excellent results of the year 2011, but will continue to achieve good sales as experts estimate it.

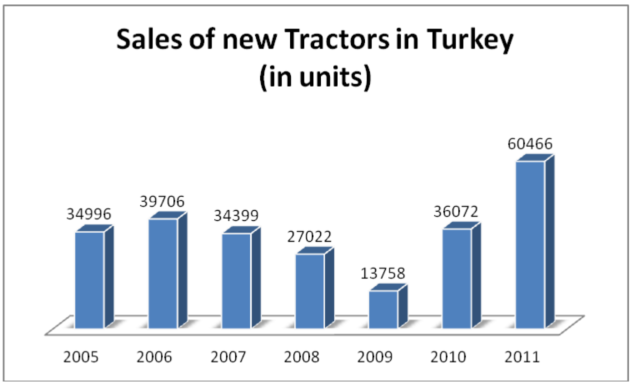

Fig. 5: The enormous increase of tractor sales in Turkey [1].

Germany has increased its weight within Europe. In terms of value, it has a share of 27% of the total agricultural machinery production in the EU, followed by Italy (18%) and France (14%). The agricultural machinery industry in Germany was able to increase its turnover by 27% up to €6.98 billion in 2011. Mowers, combine harvesters and forage harvesters from German production generated above average growth in turnover Table 1 [1].

Table 1: Production of selected machines in Germany [1].

MACHINES (in units)	**2009**	**2010**	**2011**	**Change**
Combine harvesters	6.608	5.460	8.026	**47%**
Forage harvesters	1.876	1.890	2.548	**35%**
Mowers	14.349	14.737	18.474	**25%**
Tedders and rakes	16.600	15.453	19.039	**23%**
Balers	4.807	5.474	6.548	**20%**
Ploughs	4.934	3.739	4.610	**23%**
Seed drills[1]	8.183	7.125	9.465	**33%**
Field sprayers	3.045	2.982	3.450	**16%**

[1] without precision seed drills

The number of tractors purchased in Hungary between 2005 and 2009 was 13 434 units, the number of combines was 1 892 units and altogether the agricultural machines were 18 209 units [7]. The general economic recession in Hungary affected the agricultural sector too, but the income situation of the farms improved clearly in 2011. After a relatively poor harvest in 2010, agricultural production value increased by 25% in 2011. In addition, government subsidies increased by about 15%. Hungarian imports of agricultural machinery increased by 66% compared to 2010, reaching €326 million [8]. The growth on the tractor and harvesting equipment markets was particularly high – especially the import of potato, beet and forage harvesters rose rapidly. Altogether, approximately 90% of the agricultural machinery used in Hungary is imported [9].

3.3. The importance of vocational training and education

To be effective innovators, employees constantly need to develop new skills. The innovation strategy should define some of the new skills that are needed in a company. These requirements can be compared with existing skills and, where gaps exist, they can be covered by hiring or employee development. Technological skills may need to be developed through specific training programs. A company's future requirements should be one driver for planning the development of employees' skills. However, of equal importance is the individual motivation – for many employees learning new skills can be hugely motivating [10].

In a case of a farm or an agricultural company the managers', engineers' and employees' agricultural and biological knowledge is very important which means a deep theoretical background in plant production, plant protection, soil science, animal husbandry, environment protection etc. All these scientific areas mean the basis of modern agriculture and rural development all over the world. The appearance of new materials, chemicals, medicines, technologies etc. need more time to learn them and rationally use them according to the different rules.

The technical knowledge is also important because the technical resources and equipment play a significant role in the whole production process. The intelligent agricultural tractors, harvesting and other farm machines - as it is shown in this paper - are really complicated and complex ones. It is not easy to operate or repair them. There is a number of difficult decisions have to be made concerning machinery, when we choose, buy, lease or when we sell them. Applied information technology must be also mentioned as an important area. Without this basic knowledge it is impossible to make the optimal decisions.

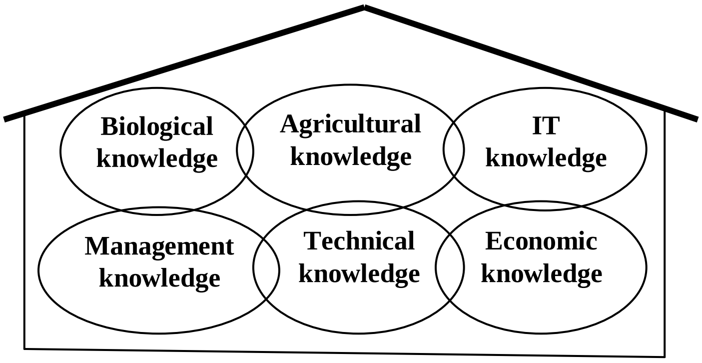

Fig. 6: Specific knowledge to manage agricultural farms.

All of these are necessary, but not enough to manage a successful enterprise in agriculture. Economic and general management knowledge is also badly needed as it is shown on Fig. 6. Strategic-, marketing-, cost-, machinery management mean the most important areas. Management skills and the application of the different management techniques and methods determine the activity and future success of the whole enterprise [11]. Properly preparing the decisions and selecting the most favorable version of the different variants are essential for both the agricultural enterprises and the national economy.

The large scale of different skills listed before have to be taught for the future managers and engineers. For the students of agricultural mechanical engineers during the university studies (graduate level) much attention has to be paid to a wide range of technical courses. Students have to learn the basic professional subjects very hard. They write during the semester quite a lot of theoretical assignments, test papers and take many exams. In the case of applied economics and management studies the situation is not the same. Some professors do think that economics, marketing, and management are important areas, but students have to learn them after their graduation in a frame of a postgraduate course.

Learning and development are closely linked. For most people, lifelong learning and development are likely and desirable. For many professionals, lifelong learning may mean meeting continuing education requirements to retain certificates. For other employees, learning and development may involve training to expend existing skills and to prepare for different jobs. Assistance from employers for needed lifelong development typically comes through programs at work, including tuition reimbursement programs. However, much of lifelong learning is voluntary, takes place outside work hours, and is not always formal. Although it may have no immediate relevance to a person’s current job, learning often enhances an individual’s confidence, ideas, and enthusiasm [12].

4. CONCLUSIONS

This paper presents the importance of sustainability, technical and machinery development in agricultural production. The three strata of automation (machine - office - field) create the long-term objective of the automation process which is the better combination of information and integration of different processes. The intelligent production methods and up-to-date technical solutions are the basis of precision farming. The present results some obstacles and future development are shortly discussed. In summary, however – even if there is still scope for fine-tuning some of the instruments – modern precision farming is a revolutionary step towards resource efficiency, protection of the environment and social sustainability.

The economic background of agricultural enterprises and the economic situation of agricultural machinery industry basically influence the future performance of the sector. European engineers and European agricultural machines and equipment are welcome all over the world. Without continuous innovation and development this advantage can disappear. Education, training and lifelong learning play an important role in creating the basis of professionals to design, manufacture, operate and maintain the agricultural machines and equipment. Complex knowledge, different skills and critical thinking can help the future generation of agricultural – mechanical experts.

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Scientific review paper

NEW SECONDARY MATERIALS FROM RECYCLED AGRICULTURAL PLASTIC FILMS

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Abstract: *The extensive and expanding use of plastic material in the Italian agriculture for several diverse application results in increased accumulation of plastic waste in rural areas. The current practices adopted by Farmers consist, unfortunately, of a mismanagement of the plastic material that is abandoned or buried in open fields or burnt in a not controlled way, with heavy environmental consequences and a loss of material and energy.*
In the present paper, an analysis of the most technical efficient and economically feasible solutions for the management of agricultural plastic waste is given. These solutions represent main results of the European Project "Labelagriwaste" and they enable the analysis and planning of agricultural plastic waste fluxes, together with the possibility to investigate different development scenarios and to consider new planning strategies for the management of agricultural plastic waste.

Key words: *agricultural plastic materials, plastic material properties, plastic waste management, mechanical recycling*

1. INTRODUCTION

The territorial management and the issues related with the evolution of the study and planning experience cannot leave out to consider and investigate the environmental and landscape aspects related or induced by agricultural, forestry and agro-food activities [12, 23, 26]. Sludge and waste that come from agricultural and agro-food sectors could be also considered when strategic planning of the territory if adequate construction for their collection and disposal is foreseen.

Agricultural wastes are many and different, from livestock slurry to pruning residues, from parts of mechanical means to by-products from agro-industries, from agrochemical products to plastic materials. Regarding the last category, post-consumed plastic waste, it should be noted that the results obtained in agricultural productivity, thanks to the increasingly widespread use of plastic materials, especially in protected crops, are appreciable both from the economic and productive point of view. In fact, plastic films, characterized by low cost, ease of installation, low labor demand, lightness, ability to save energy and water, reduction of agrochemical consumption, etc., replaced other traditional materials, such as glass and paper to cover greenhouses or straw mulching for soil [8], significantly influencing the quality of the production and marketing (packaging, transport, storage and sale) of agro-food products with a positive impact on farmers' income.

The continuous innovation in polymer technology and plastic production helps to explain that, since 1950, plastic production has increased on an average of almost 10% every year on a global basis. In order to enable better production conditions and higher yields wide range of conventional polymers, such as PE, PVC and EVA, have been used in agriculture as greenhouse covering materials and as mulching materials.

The world consumption of agricultural plastics amounts yearly to 6.5 million tons; the official statistics suggest that they comprise less than 4% of the total plastics consumption in USA and 2% in Europe [15, 27]. Countries with the highest consumption of plastics are Mediterranean countries (Italy, Spain and France). Specifically, Italian agriculture absorbs about the 3% of the produced plastic materials, about 380.000 tons, the majority of which are films, nets, pipes and containers of various shapes and sizes (Table 1).

It is estimated that, currently, Italian agriculture generates 240,000 tons of plastic waste per year (Table 2) that causes severe environmental risk, considering that, at the end of their useful life, they are often poorly managed and disposed in different way from that contemplated by the Italian law in force.

Therefore, adequate and rational plans for the collection and disposal are needed. In the same way, there is a need for establishment of an appropriate traceability system for the agricultural plastic chain, especially for the regions characterized by intensive agriculture [3, 11, 12, 20, 22, 28].

Table 1: Main agricultural application of plastic materials (*Source*: CIPE, 2006).

AGRICULTURAL APPLICATION	Consumed (t/year)	PRODUCED EFFECT
FILMS (Greenhouse and tunnel, Low tunnel, Mulching, Nursery films, Direct covering, Covering vineyards and orchards)	133,000.00	• protection crops by meteorological phenomena, • control and climatization of the inside environment to obtain increased yields, production of early fruits and late harvest; • reduction of herbicide and pesticide; • frost protection and water conservation; • floating mulch; • soil solarization.
NETS	5,300.00	• protection from sun radiation, hail, wind, snow, or strong rainfall in fruit-farming and ornamentals; • shading nets also for greenhouse applications during the summer, cooling the inside microclimate;. • protection against virus-vector insects and birds; • harvesting of small fruits (olives, almonds) and post-harvesting operations (collecting of cut flowers and drying of fruits); • shading mushroom-beds; • shading of shelters for cattle breeding
PIPING, IRRIGATION /DRAINAGE	138,000.00	• water reservoir; • channel lining; • irrigation tapes and pipes; • drainage pipes; • micro-irrigation; • drippers.
PACKAGING	50,000.00	• fertilizer sacks; • agrochemical bottles; • containers; • tanks for liquid storage; • crates.
OTHER	55,000.00	• silage films; • fumigation films; • bale twines; • bale wraps; • nursery pots; • pots for ornamental plants and flowers; • soilless culture substrate; • strings and ropes.

Table 2 Estimated quantities of agricultural plastic waste per year in Italy

Agricultural Application	Covered surface	Consumed plastics	Lifetime	Produced waste
	ha	t	months	t/year
Greenhouses and large tunnels films	26,000.00	57,000.00	36	19,000.00
Low tunnel covering films	27,000.00	30,300.00	12	30,300.00
Mulching films	90,000.00	43,250.00	12	43,250.00
Direct Covering	12,000.00	2,500.00		
Nets		5,300.00	96.00	663.00
Silage film, bale wrap film		8,500.00	12	8,500.00
Micro irrigation systems	113,000.00	130,000.00	24	65,000.00
PP twine for hay and straw		10,000.00	12	10,000.00
Fertilizers sacks		12,000.00	12	12,000.00
Pesticide cans		2,500.00	12	2,500.00
Semi rigid sheet tanks, pots, crates, packaging fresh production other (pipes for drainage, application for mushrooms, tobacco, cattle, etc)		2,000.00 10,000.00 8,000.00 17,000.00 32,000.00 11,000.00 **80,000.00**	6 - 36	50,000.00
Total		**381,000.00**		**241,213.00**

2. MANAGEMENT OF AGRICULTURAL PLASTIC WASTE

2.1. Environmental impact on rural territory

Agricultural plastic wastes represent an environmental and economic problem [23] since yearly they generate a flow that doesn't often follow a rational treatment process [21]. In fact in many cases, Italian farmers dispose plastic waste both forgetting the community and environmental interests and ignoring the national legislation in force.

The Table 3 shows some usual common practices for the agricultural plastic waste disposal and their negative consequences [12].

From the economic point of view, these practices determine a non-recovery of post-consumer plastics, which results in a considerable dissipation of energy and material.

Table 3: Common agricultural waste disposal schemes.

PRACTICES	CONSEQUENCES
Abandonment in the fields, along waterways or landfills	• severe and diffuse pollution and degradation to the landscape and environment, damaged (vulnerable) areas that are very often characterized by natural beauty and attractive tourist sites; • risk for domestic and wild animals; • obstruction to the natural water flow; • exhaustion of landfills causing environmental and economic impacts.
Burying in the files	• qualitative degradation of the soil; • irreversible contamination of the soil; • potential threat for the safety and quality of food produced on these areas.
Burning in the open field and in uncontrolled sites	• release of harmful substances, such as CO_2, CO, H_2S, SO_2, NH_3 and dioxin, in higher quantity per mass of material burned than the emissions from controlled incineration (e.g., 20 times as for dioxin; 40 times as for particulate matter, Travis and Nixon, 1991) due to inefficiencies of open combustion. In particular, plastic burning produces large CO_2 emissions (about 3,0 Kg of CO_2 per Kg of Polyethylene) therefore, if incineration is uncontrolled, this quantity is completely introduced in the atmosphere with the well-known negative consequences without any exploitation of energy or heat production; • release of combustion residues harmful to human and animal health through direct exposure - inhalation or dermal contact - or indirect - ingestion of plants or animals food contaminated, as well as polluting the soil and groundwater.

2.2. Post-consumption plastic waste

Generally, the European legislation on waste management is aimed at post-consumer waste from end-of-life products such as packaging, automotive, electric and electronic equipment, while a few countries, including Italy, have the legislation on agricultural waste management. Nevertheless, in Italy only a part of agricultural plastic waste is collected, transported and recovered in a controlled way by the “PolieCo” [11], the “Italian Consortium for the recycling of the PE materials”, except PE packaging, established by law in 1997. As part of their obligation to a sustainable agriculture, the plastic manufacturers, distributors and farmers are urged to ensure the safe disposal of agricultural plastic waste.

Agricultural plastic waste, such as silage films or greenhouse films, is a good input for mechanical recycling as it is made from a limited range of plastics, mostly polyolefins but the problem with these materials is that they are different in their properties. Recycling process of the silage film (as in UK) is cheaper because material is clean enough or is easily cleanable. Recycling of greenhouse films is more expensive because they are contaminated not only by plant material but mainly by particles of chemicals (pesticides and fertilizers) and particles of soil. Problem in recycling is when the plastic is mixed with recycle ferrous material (rings passes ties and metal spikes) as in the case of films and nets for covering vineyards and orchards. The situation worsens because the recycling process becomes more difficult and costly, since, in addition to the normal phases of cleaning and washing, the plastic waste must be previously separated from other foreign materials.

Unfortunately, in the year 2010 (as happened in the last 7 years), only 34% of the total post-consumption agricultural PE was recycled in Italy [16], according to the Italian Consortium “PolieCo”, a small amount if compared to Norway that manages, recovers and recycles virtually 100% of agricultural plastic waste. The low percentage of recycled material in Italy is due to the illegal trade of APW to other Countries, principally China. In 2012 year, the Italian financial police stopped a merchant-ship, containing 750,000 containers, that was leaving for China [16].

Solving the problem of waste agricultural plastic is possible applying some of the different strategies, such as:

a) increasing the lifetime duration of the materials by means of additives and proper applications and installation,
b) reducing the material thickness,
c) introducing and promoting the use of bio-based materials as alternative to the traditional plastic films produced with fossil raw resources,
d) transforming the plastic waste in resources

In reference to the biodegradable materials, biodegradable transparent films for covering the low tunnels and black or green films for mulching, based on maize starch as raw material (Mater-Bi) and biodegradable polyesters are nowadays available [2]. Unfortunately, a very small percent of the Italian agricultural land (4,000 hectares) is covered with biodegradable mulching films of Mater Bi used for crops with a cycle between 60 days and 6 months. Probably, the low diffusion of this material is due to the current price that is still higher than the LDPE films, with the same thickness and productive performances.

If the costs of plastic film collection, disposal and recycling process are taken into account by farmers, the price of the bio-based are comparable to the traditional ones [21].

2.3. Transforming the plastic waste in resources

2.3.1. Technological solutions for rational disposal

The main aim of the strategy to be pursued for optimal collection and disposal of waste is, in general, its transformation into resources that is in “secondary raw materials”. The strategy followed by the European Union (91/156/EC, 91/689/EC, 94/62/EC) was implemented in Italy by Legislative Decree No. 22 of 5 February 1997 (better known as "Ronchi" Decree), and subsequently repealed by Legislative Decree No. 152 of April 3, 2006 (and its upgraded), "environmental Regulations" in force on waste. According to them, waste management is an activity of public interest that must be carried out avoiding any damage to the environment and public health. At the same time, they preserve the hierarchical structure to follow in order to reduce the adverse impact of the agricultural plastic waste [8].

The management system must necessarily be rational and, above all, ensure an effective and lasting solution of the problem, contributing to the evolution in the waste management that, although slowly, is happening in Italy. This is "necessary but inevitable evil" that points to the enhancement of "secondary raw material" of the waste resource for a sustainable solution under the economic, social and environmental aspects [9, 11]. Aspects related to a rationalization of collection, transport, storage and final disposal of agricultural plastic waste have been the subject of the Scientific Research Project "Labelling agricultural plastic waste for valorizing the waste stream - Labelagriwaste", funded by the European Commission (Contract No. COLL-CT-2005-516256). Project results showed that the main options, able to ensure compliance with environmental and economic constraints, for the final disposal of post-consumed agricultural plastics, are mechanical recycling and energy recovery [4, 6, 7, 11, 18, 28].

2.3.2. Mechanical recycling

Mechanical recycling is the reprocessing of plastic waste, rigid or flexible, to produce raw materials to be used in the construction of new products. The waste is subjected to washing, grinding, milling and subsequently drying.

The different types of structures and use during the lifetime of the commercial PE strongly influence the recycling behavior of these materials. Indeed the presence of branching changes the degradation kinetic and then the final properties of the recycled material after repetitive processing steps. This behavior is particularly important for those plastic materials that are subjected not only to thermo-mechanical degradation during reprocessing operations, but also to some other types of degradation during their lifetime. Indeed, photo-oxidation or other types of degradation induce different structural and, as a consequence, morphological changes depending on the structure of the polyethylene [7]. The structure of the reclaimed LDPE coming from agricultural films, can be modified because the degradation is usually severe. For example, a dramatic reduction of the elongation at break is possible with the increasing of the exposure time; so, after about one year the ductile polymers become fragile. Of course these results cannot be generalized because they depend on the amount of solar energy, mostly UV radiation, absorbed by the polymer. The level of degradation, and then the level of structural and morphological modification (as remarkable amounts of oxygenated groups as result of photo-oxidative mechanisms) undergone by the polymer during its lifetime, determine the properties of the secondary material [17]. The main modifications are the increasing of the value of the melt index and a decreasing of the molecular weight; this latter and the presence of less deformable structures reduce the elongation at the break and this premature breaking can decrease the tensile stress [7]. The important feature to point out is that even if monopolymer blends are made up of two materials with the same chemical composition, but with some differences in molecular weight and chain structure (it is the case of the virgin/recycled homopolymer blends) because the eventual presence of the “alien” chemical group, present in recycled parts owing to photooxidative degradation, can alter properties, making the blend not suitable [18]. PE recovered from agricultural uses is a typical example. In fact this material contains an oxygenated group as a result of photooxidation, crosslinks, additives and stabilisers. Moreover, these films include in their formulation other polymers than ethylene such as vinyl acetate (in case of EVA films). Differences in the rheological properties of the virgin PE and of the recycled PE are also due to the presence of additives that are typically used in films for agriculture. In this case it is clear that even if the two starting materials are thought to be the same PE, they may be significantly different and give rise to incompatible blends [18]. It can be concluded that the final properties of the blend depend on the amount of degraded polymer but mainly on the extent of degradation. When degradation of the polymer is limited, good properties can be achieved, but if the degradation effects are more pronounced, there is a general worsening of all the properties [5, 14, 15, 19, 24, 25].

Depending on the characteristics of APW (homogeneity, cleaning and deterioration), the resulting material can be recycled, giving rise to two types of products: a granule of a higher category, such as to, subsequently, come in turn reused for the realization of new film [10, 13], albeit to a lesser level of technological applications; or when the APW does not have high quality properties, the extrusion process is performed in order to produce solid section profiles (rectangular, circular, etc.) which can be used as support structures, being characterized by properties and workability similar to wood.

Therefore, further investigation should be made on blends, paying particular attention to the formulation of the compounds to be recycled, both on the share of waste specimens in the mixture and on specific additives, in order to optimize and improve the mechanical and spectral properties of new recycled materials.

2.3.3. Energy recovery

For waste fractions that do not allow an economically optimal material recovery, such as recycling, energy recovery by combustion is probably the only alternative to landfill disposal, thank to its high calorific value, similar to oil, from which it originates. This is especially true when dealing with high calorific value waste fractions and low biodegradability, such as plastics (Table 4). Highly degraded or soil contaminated plastics, that cannot be mechanically recycled can be successfully used as an alternative fuel in power plants or in cement factories. In energy recovery the plastic behaves as a fuel: 1 ton of plastic gives off as much energy as 1 ton of oil [1].

Agricultural plastic waste could make an ideal replacement for regular fuels. By using plastic as fuel, other primary energy sources, such as gas, oil or coal, can be conserved. This therefore fulfills the basic idea of recycling, i.e., to conserve raw materials and reduce waste.

Of course, to be economically viable and technically valid, some conditions must be fulfilled, which respectively are low costs of storage, transportation and separation of materials, and material devoid of high levels of impurities (earth, moisture, chlorine, sulfur, heavy metals, etc.) or otherwise their values should be present within limits set by the plants.

Table 4: Caloric values of plastic materials, compounds, products and fuels [1].

Materials, compounds, fuels	Caloric value, MJ kg^{-1}
Polyethylene	46.0
Polystyrene	46.0
Polyvinyl chloride	18.9
Paper and wood	16.0-16.8
Methanol	22.7
Natural gas	53.4
Propane	50.0
Kerosene	46.5
Gasoline	45.9
Gas oil	45.6
Anthracite	29.7
Charcoal	33.7

Also in this case it is possible to distinguish between two classes, based on the characteristics of the waste. A category, consisting of waste agricultural plastic that does not need to be mixed with other alternative solid fuels and that can be used as fuel in cement plants, after being subjected to treatments to prevent impurities that could affect the performance of the clinker, as well as to prevent the release of harmful substances in the flue gas and in the atmosphere. Alternatively, in the absence of better solutions, the waste may be sent to cogeneration plant of electricity with waste heat recovery, in combination with other waste categories. Unfortunately, in Italy, for energy recovery only plastic materials from Urban Solid Waste are used while APW also is not considered.

2.3.4. Landfill

Agricultural plastic waste that cannot be subject to the above-mentioned disposal techniques (non-usable waste resulting from recycling processes, waste of energy recovery processes, mulching films with large amount of soil residues, etc.), will be destined for final disposal in landfills.

3. CONCLUSIONS

Agricultural plastics have been used worldwide in the last 50 years thanks to numerous properties such as versatility, lightness and low cost. In agriculture, the use of plastic materials results with many and different benefits such as increasing of the yield and the quality of production and a more efficient use of agricultural land. Consequently, a large amount of agricultural plastics waste is produced and, if not properly collected, treated and recycled, pollutes the rural areas and releases harmful substances in the environment. Even worse, when APW are illegally burned, many pollutants can enter the food system at the base of the food chain.

Therefore, the strategies to reduce the environmental effects of the plastics use in agriculture are: the increase of the lifetime duration of the materials by means of additives and proper applications and installation; the reduction of the material thickness; the introduction and promotion of bio-based materials and, a correct procedure for the collection, disposal and recycling of post-consumption plastics. For this last option, all stakeholders of the agricultural plastic chain should be more awarded and involved in the operations of production, use, collection and storage, according the Italian legislation in force. In particular, rewarding mechanisms should be, for producing companies, able to introduce traceability systems of materials in order to make more rational and efficient the collection-transport and disposal system.

Subsidies and facilities (e.g. logistic, equipment for collection, storage and recycling, economic and legal advices) should be programmed for farmers and/or associations of farmers in order to motivate them to adopt suitable and right collection practice.

Finally, the activity of the National PolieCo Consortium should be further propagated and spread to all Italian agricultural enterprises (commercial farms), the small and isolated ones too.

It can be concluded that there are several and significant aspects to improve and guarantee a suitable management system from collection and transport to a correct disposal, regardless the waste typology and consisting, above all, of mechanical recycling and energy recovery, that transforms agricultural plastic waste into a secondary raw material.

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Original scientific paper

A EUROPEAN SYSTEM FOR THE WASTE MANAGEMENT AND VALORISATION OF EMPTY PLASTIC CONTAINERS OF AGROCHEMICALS

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Abstract. *Mismanagement of Agrochemicals Plastic Packaging Waste (APPW) constitutes a major environmental problem, resulting in the pollution of soil, air and water resources and compromising the agricultural products safety, the protection of the environment and the public health. Systems for the management of APPW established in some European countries are incompatible while their operational conditions and technical criteria could be improved. In many countries no schemes exist yet for the management of APPW with serious negative consequences for the environment and public health. In response to these problems the European project AgroChePack has developed an environmental friendly, economically viable European APPW management scheme by transferring know-how from existing schemes, designing a new integrated APPW management scheme and testing it through pilot trials in five countries. This work presents the basic design principles established by AgroChePack to develop an integrated APPW scheme and the pilot trials in Greece.*

Key words: *agrochemicals, packaging, hazardous, waste, recycling*

1. INTRODUCTION

Mismanagement of Agrochemicals Plastic Packaging Waste (APPW) constitutes a major environmental problem, resulting in pollution of soil, air and water resources and compromising the agricultural products safety, the protection of the environment and public health. Some schemes for the management of APPW have been established in a few European countries, as in Germany (*Pamira* [1]), France (*Adivalor* [2]), Spain (*Sigfito* [3]). However, these schemes are incompatible with each other while in most cases they are not combined in a synergic way with the management of other Agricultural

Plastic Waste (APW) categories to optimise use of resources, increase efficiency and reduce cost. In many other countries (e.g. Greece, Italy, Cyprus) no schemes exist for the management of APPW with serious negative consequences for the environment and public health.

In response to these serious problems, a European project, the *AgroChePack* project [4] was lunched, aimed to develop an integrated, efficient, environmentally friendly and economically viable APPW management system in Europe by transferring know-how from existing schemes and by promoting synergy with the *LabelAgriWaste* [5] project (APW). This new integrated APPW management scheme was designed and piloted in five EU countries. The five participating Mediterranean European countries (Greece, Italy, Cyprus, Spain and France) are among the major European consumers of agrochemicals, with large agricultural areas. They consumed 20.6 kg/ha of agrochemicals in 2003 [6] while during the last years this amount increases steadily. According to Eurostat, France, Spain and Italy are the major consumers of plant protection products (PPP) in EU (nearly 75% of the total of 220.000 t of PPP used in EU-25). As a result a high volume of packaging of agrochemicals waste is generated that should be valorized preferably through recycling, or energy recovery if not recyclable.

This work presents the basic design principles established by the *AgroChePack* project [**Error! Bookmark not defined.**] aiming at the environmental friendly and economically viable APPW management scheme in Europe. Its pilot implementation in Greece is also presented.

2. THE AGROCHEPACK SCHEME

2.1 Design principles of the AgroChePack APPW management scheme

The basic design principles established by *AgroChePack* [4] in terms of safety, efficiency and cost include:

a. Decontamination: Development of a protocol for rinsing and decontaminating APPW in order to characterize them as non-hazardous waste.

b. Control: Development of a secure mechanism to assure effectiveness of the rinsing method.

c. Sorting: Sorting and separation of decontaminated, clean APPW to categories of homogenous materials.

The *AgroChePack* [4] system integrates several key technical procedures developed in support of the basic design principles as follows:

a) Decontamination of the APPW and control:

- Definition and application of a reliable, scientifically justified, decontamination methodology that ensures meeting the relevant EU legislation criteria for non-hazardous waste
- Design and implementation of a simple, reliable traceability scheme
- Establishment of a quality assurance scheme (guidelines, check points, sampling and analysis or hazardousness)

b) Sorting the decontaminated APPW at the source to homogeneous material piles:

- Identification of recyclability criteria and definition of sorting categories
- Grouping of non-recyclable APPW that comply with alternative solid fuels (ASF) for energy recovery specs

The aim of the design principles is to achieve the best exploitation of the APPW by:

- Enhancement of recycalbility of collected APPW
- Minimization of non-recyclable APPW

The development of the *AgroChePack* scheme followed three steps at regional level:

- Quantified analysis of the APPW generation
- Design of the APPW management logistics and infrastructure
- Pilot implementation, evaluation, optimization

2.2. Mapping of APPW generation

To design the scheme for a specific region, it is important to know the waste generation map including the temporal-spatial distribution of APPW generation. *AgroChePack* starts with the mapping of the dominant cultivations for the area. Then, the key parameters needed to estimate the APPW generation, are quantified: type/dosage of main agrochemicals used per cultivation, application time, material and size of package for each agrochemical. The final outcome is the quantified temporal-spatial APPW generation (weight and volume per material category per month).

2.3. Design - Decontamination of APPW

2.3.1. Decontamination methodology

In 2008, the FAO/WHO published *“Guidelines on Management Options for Empty Pesticide Containers”* [7] recommending properly rinsed containers that have been inspected as non hazardous. In the United States, the federal Resource Conservation and Recovery Act (RCRA) of 1976 makes it illegal to dispose of any pesticide or pesticide-related waste by burning, dumping, or well injection [8]. Any container with unused pesticide, including residue, is considered to be hazardous waste which may harm humans, animals or the environment. However, properly rinsed containers are not considered hazardous waste and can go to an approved recovery/recycling centre.

In Europe, threshold concentrations have been set for the different categories of active ingredient. The limits depend on the hazardous nature of the active ingredient concerned. Waste consignments containing active ingredient concentrations below these limits are classified as non hazardous. The concentration of the active ingredient is expressed as a percentage of the total weight of the waste consignment. There is a wide range of threshold limits with the lowest European limit being 0.1% w/w for ‘Very Toxic’ active ingredients [9]. The European Waste Catalogue (EWC) [10] links the classification of certain hazardous waste categories to the concentrations of dangerous substances within the waste. The two lowest threshold EWC limits are [11]:

- *“one or more substances classified as very toxic at a total concentration ≥0.1%”*
- *“one or more substances classified as toxic at a total concentration ≥3.0%”*

A weakness of the existing APPW management schemes is that in some of them the tripled rinsed APPW are classified as hazardous whereas in others as non-hazardous [**Error! Bookmark not defined.**]. The cost for managing hazardous waste is prohibitive.

According to ECPA [**Error! Bookmark not defined.**], effective rinsing of packs is achieved by manual triple rinsing, pressure rinsing or mechanical integrated pressure rinsing (equipment is present in modern pack and sprayer designs [12]). The quantity of dangerous substances that remains in the container, either as residue after rinsing or migrated into the plastic, determines the classification of the empty container based on the EWC limits.

It has been scientifically proven that the triple rinsing methodology can decontaminate effectively APPW [**Error! Bookmark not defined.**,13]. The results of another study by ECPA (2002) [**Error! Bookmark not defined.**] indicated that the total amount of active ingredient in correctly rinsed containers remains well under the threshold for very toxic substances of 0.1% w/w set by the EWC. According to CropLife [**Error! Bookmark not defined.**], triple rinsing removes more than 99.99% of contaminating residue when applied to containers made of appropriate material (such as High Density Polyethylene). A key point in the success of *AgroChePack* is to ensure that the APPW is properly triple rinsed. According to *AgroChePack*: Firstly, the triple rinsing procedure must start immediately after the application of the agrochemical to avoid solidification of the agrochemical. The rinsate is driven directly into the sprayer's tank and is used during the spraying of the agrochemical. Secondly, the person who will apply the rinsing must be appropriately trained on the methodology of triple rinsing. Only registered and trained farmers are accepted to the *AgroChePack* APPW management scheme.

2.3.2. Quality assurance - Traceability

Quality assurance with respect to decontamination is ensured in *AgroChePack* through sampling and hazardousness analysis of the collected sample. The proper implementation of hazardousness analysis requires the development of the sampling methodology. The scope of the sampling methodology is to define where and how to sample and the sample quantity to collect to assure the sample represents the APPW pile.

The traceability scheme consists of: The registration of the farmers who participate to the *AgroChePack* scheme and their training, and the recordkeeping of the data of the agrochemical packages used, triple rinsed and accepted to the scheme. A database of the participating farmers is generated and appropriately trained managers assume responsibility for the recordkeeping. It is expected that the traceability scheme will eliminate illegal agrochemicals or mismanagement of agrochemical packages as the relevant legislation will be enforced. The traceability scheme will also allow transparency through quantification of the APPW collected and recycled to justify funding of the scheme by the relevant national recycling agency.

2.4. Design - Sorting of decontaminated APPW

2.4.1. Recyclability of APPW

The aim of the *AgroChePack* scheme was to achieve the best exploitation of the collected APPW by enhancement of the percentage and the quality of the decontaminated APPW in terms of recyclability. *AgroChePack* sorts the containers according to their composition into 2-3 main categories. The sorting depends on the range of the most common packages used in the specific region where the scheme is applied (e.g. *"HDPE"*

(High Density Polyethylene), "COEX" (Coextruded), "CAPS") and the category "*Others*". The last category includes packaging materials that do not belong to the first two main categories (e.g *PET (Polyethylene Terephthalate)*, flexible *LDPE (Low Density Polyethylen*e) bags, metallic containers etc). The majority of APPW materials collected and decontaminated belongs to categories *HDPE/ COEX*. *COEX* containers are made of *HDPE* polymer matrix with their inner surface covered by a thin coating made of another polymer, used as barrier, being impermeable to the specific substances that can penetrate the *HDPE* matrix. For specific agrochemicals, the companies use exclusively *COEX* containers and for others *HDPE* containers. Some companies may use either *HDPE* or *COEX* or other plastic containers for the same commercial agrochemical. No specific rule is applied for the use of the different materials. The choice is made on a case by case basis by each company, mainly depending on the agrochemical and its characteristics.

In cases of plastic packaging of unknown composition commonly used in a specific region, the safest way is to conduct an Attenuated Total Reflectance - Fourier transform infrared spectroscopy ATR-FTIR on both surfaces of containers and identify the main components from these spectra. In the cases of *COEX* containers, usually in the form of PE/EV (polyethylene/ethylenevinyl) and PE/PA (polyethylene/ polyamide), a relatively high proportion of the secondary component (EV or PA in this case) in the matrix could compromise the recyclability of the container. The criteria for the *COEX* packages that can be recycled follow the corresponding specs of the *LabelAgriWaste* project [14]. If needed, a DSC (differential scanning calorimetry) analysis of the container could provide a good estimation of the recyclability of APWW containers.

2.4.2. Energy recovery criteria concerning APPW

The decontaminated packages that do not fulfill the criteria for recycling (category "*Other"*) can be directed to specific industry for energy recovery. Industries, especially cement kilns that have high temperature kilns and have obtained license for using these plastics as alternative solid fuels can use the decontaminated APPW that cannot be recycled, as alternative fuel. The priority of the *AgroChePack* scheme is mechanical recycling. Energy recovery is considered an option only for non-recyclable APPW.

2.5. Design of the scheme's infrastructure

The implementation of the APPW management scheme is based on the particularities of the region. In cases of small farms with use of small capacity sprayers, the farmers are obliged to apply the triple rinsing by their own at the farm without any supervision and deliver the triple rinsed containers to the managers at designated collection stations. The managers are responsible for bringing the collected clean APPW to a regional central collection station. The whole chain is controlled through the established traceability system. In other cases, farmers use large capacity sprayers mounted on large size tractors destined for arable crops fields. They use special water filling stations designed for common use. In each geographical region, the *AgroChePack* design of the infrastructure is based on the temporal and spatial distribution of the APPW generated in the region.

2.6. Pilot implementation of the APPW scheme

In the framework of *AgroChePack*, alternative pilot schemes of the system that meet regional particularities were designed. The pilot schemes were tested in five countries [**Error! Bookmark not defined.**]. In Greece, the *AgroChePack* scheme was pilot implemented in the arable land of the municipality of Visaltia [**Error! Bookmark not defined.**], located northeast of Thessaloniki in central Macedonia.

3. AGROCHEPACK PILOT TRIALS IN GREECE

3.1. Mapping and analysis of APPW generation

A major difficulty encountered during the mapping of the APPW in the case of Visaltia was the lack of official and reliable statistical data. The needed information was obtained through interviews and information provided by local agronomists or retailers. The data collected were cross checked to provide a good estimate of the current situation.

Temporal - spatial quantities distribution of APPW were calculated per agrochemical type and agrochemical package material expressed in terms of containers volume and weight to be disposed at specific time (month) and specific location. Fig. 4 presents an example of the estimated temporal - spatial distribution of the generated APPW materials in the case of the Municipal Department of Flabouro.

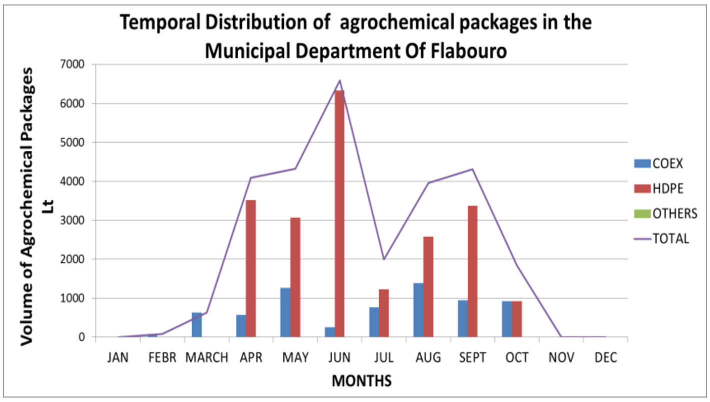

Fig. 4 : Temporal distribution of APPW volume generation in the station of Flabouro.

3.2. Design of the pilot *AgroChePack* scheme's infrastructure in Greece

In the case of the municipality of Visaltia, the majority of the farmers use large capacity sprayers mounted on large size tractors. They fill their sprayers with the agrochemicals in specific water supply points constructed for that purpose. Based on the mapping and quantified analysis of APPW generation in the region, two water supply points (in the municipal departments of Flabouro and Patrikio) were selected to serve for the decontamination and temporal storage of the empty packages and the first level quality control and traceability of the system. The selected water supply points were transformed into *AgroChePack* pilot local collection stations of the municipality of

Visaltia (**Error! Reference source not found.**). The local stations were designed and constructed to facilitate movements of large tractors with sprayers and improve the ergonomy of the infrastructure of the water supply for triple rinsing and they are fenced. The *AgroChePack* local collection stations include a small protected storage facility specially designed for the sorting, recording and the temporal storage of the collected APPW. The pilot stations were in operation for eight months for data collection, monitoring and system optimisation. A central APPW consolidation station was designed and constructed at the location of the municipal recyclable waste consolidation station (Fig. 5).

3.3. Sorting, Labelling & Storage

According to the proposed APPW management scheme the package material was the key element used to sort the collected decontaminated APPW into four categories. The bags of the fertilizers formed a separate homogeneous pile. The collected APPW of each material category were placed in labelled designated plastic bags inside the storage area of the local collection stations. Information about the period of APPW collection, the code of the station and the material category of APPW was recorded on each bag for traceability purposes. These data were also kept in the files of the station.

Fig. 5: The *AgroChePack* pilot local collection stations of Flabouro and Patrikio (top) and the central consolidation station (Mun. of Visaltia) (bottom).

3.4. Operational protocol of the stations

Systematic dissemination and training is required for the correct operation of the stations. The local collection stations collect agrochemical containers that are triple rinsed on site and containers decontaminated by the registered - trained farmers on their own responsibility. The decontaminated containers are placed in designated bags according to their composition under the guidelines of the supervisor. The supervisor provides the farmer with a certificate of compliance. When the volume of the stored decontaminated agrochemical packages in the local collection station reaches a predefined level, they are transported to the central consolidation station where they are recorded and stored, once again sorted in the four homogenous categories. From the central consolidation station the APPW are delivered to the final disposers for recycling ("*HDPE", "COEX", "CAP"*) or for energy recovery ("*Other"*), when the collected APPW reach a certain quantity.

3.5. Decontamination of the collected APPW

The efficiency of APPW decontamination through the pilot trials was evaluated by implementing alternative sampling and analysis methodologies. Lab tests were conducted independently by the *AgroChePack* teams of the University of Lleida and the Agricultural University of Athens, in collaboration with Benaki Phytopathological Institute [15], to verify the reliability of the triple rinsing methodology applied through the pilot trials. The results of the tests confirm that the triple rinsing method is easy to apply by trained farmers (under supervision) and that when applied correctly and under control it meets the relevant thresholds set by the European Waste Catalogue [**Error! Bookmark not defined.**].

The existing analysis methodologies of decontaminated APPW to characterize them as non-hazardous waste according to the EU hazardous waste provisions were also evaluated. The inter-laboratory tests aimed at the scientific verification of characterizing appropriately triple-rinsed APPW as non-hazardous waste according to EWC provisions.

3.6. Sampling methodology

In the absence of pilot data and based on the scarce literature data a sampling methodology was established based on the analysis of the samples collected at the pilot stations. It consists of the sampling of APPW transported from the pilot stations and stored at the consolidation station: all plastic bags to be inspected visually for contamination; the ones with possible contaminated products to be opened and sample from it the ones that appear to be the most contaminated; a minimum of 3 containers to be taken from bags coming from each local station and sent for analysis. In addition, at least one out of five bags arriving at the consolidation station is to be rolled and visually inspected to contain homogeneous material.

3.7. Hazardousness laboratory analyses of APPW

Experimental laboratory hazardousness analysis was conducted at the facilities of BPI to define the details of the triple rinsing procedure that will effectively decontaminate any container and agrochemical substance and test the analytical laboratory methods used to detect accurately the hazardousness of the triple rinsed container.

To assure the efficiency and universality of the proposed decontamination procedure, some of the most difficult to rinse commercial agrochemicals were chosen from the list of the commonly used ones in the area of the pilot trials. Among them, viscous components and dispersions in oils (OD) and solid suspensions (SC) as well as solid powders [[16]]. The triple rinsing procedure was applied at the laboratory on the selected commercial agrochemicals (two to four containers for each product) following the protocol established by *AgroChePack* [4]..The analysis of the empty containers was done at the facilities of BPI in collaboration with AUA by rinsing the empty triple washed container with the most suitable solvent for the particular active substance contained and by using the analytical method recommended by the producer of the active ingredient. As shown in [16] the detected active ingredient remains in the properly triple rinsed containers are several orders of magnitude bellow the hazardousness threshold limits defined by EEEC regulations [**Error! Bookmark not defined.**]. In all cases the remains were found to be even below the strictest threshold of 0.1% w/w (remains/container), applicable to very toxic agrochemicals. This proves the efficiency and safety of the triple rinsing, when applied properly.

A possible absorption of agrochemicals in the plastic matrix of the containers that could not have been detected by rinsing the interior container surface with the solvent was also investigated to ensure that such a possibility cannot influence the hazardousness analysis results. This was investigated by scraping at random the interior surface of the containers already rinsed by the solvent. The scrapings, with an average size of the particles of 70 μm were rinsed with the same solvent to detect and quantify the presence of active ingredients. The results [16] showed that in all cases the quantities absorbed by the most affected thin internal layer of the plastic matrix, normalised with respect to the scrapings weight, remain below the strictest threshold of 0.1% w/w applicable to very toxic agrochemicals. When these quantities are normalised to the total APPW quantity the absorption effect of the remains appears to be insignificant.

Containers were also sampled and analysed during the pilot trials. The remains were found to be below the thresholds, even of the strictest threshold of 0.1% w/w (

Table 2).

In a second sampling round performed at the consolidation station during the pilot trials, twenty of the most visually contaminated containers were sampled in duplicate. Emphasis was placed on sampling the most toxic products. From each pair of the samples collected, one of the containers was sent for analysis to the University of Lleida while the other one was analysed by BPI. BPI, in collaboration with AUA, analysed the interior surface of the bottles and after scrapping, it also analysed scrapings obtained from the interior surface of each container for absorbed active ingredient remains. A different approach was adopted by the University of Lleida: the interior surface remains were analysed first and then the entire container was pulverised and any remains absorbed by the plastic bulk were extracted. The remains in all containers analysed by the University of Lleida (20 containers with 22 different substances) were found to be below the strictest threshold of 0.1% w/w, rendering the collected APPW non hazardous. Similar results were obtained for the samples analysed by BPI, including the analysis of scrapings of the interior surfaces.

Table 2: Hazardousness analysis results of containers from the pilot trials.

Active Ingredient	Commercial Name / Formulation	Remaining ingredients as a function of APPW weight (% w/w)	Classification R-phrases (EWC, 2002) / Hazardous Waste Threshold Limits (% w/w*)
Nicosulfuron 4% w/v	Nicosulfuron MAGMA Solid concentrate	**0.00074**	R36/38, R43, R50/53 **(10%)**
	Nicosulfuron 45SC AGROLOGY Solid concentrate	**0.00012**	
	Milagro 4SC SYNGENTA	**0.00036**	
	Nicogam 4SC ΑΛΦΑ Solid concentrate	**0.00031**	
Nicosulfuron 30% w/w Rimsulfuron 15% w/w	Stead past Duo 45WG DUPONT	**0.00092**	R36/38, R41, R43, R50/53, 51/53, Xn, N **(10%)**
Quizolofop-p-ethyl 5% w/v	quizolofop-p-ethyl 5EC	**0.00003**	R10, R20/21, R36/38, RO3, R51/53 R41, R22, R37, R50/53, **Xn, N** **(25%)**
	Quizalon 5EC AGROLOGY	**0.00023**	
	Quizalofop-P-Ethyl ΝΙΤΡΟΦΑΡΜ 5EC	**0.00072**	
	jaguar 5EC ΑΛΦΑ	**0.00001**	
	jaguar 5EC ΑΛΦΑ	**0.00001**	
Mesotrione 3,75% w/v S-metolachlor 31,25% w/v Terbuthylazine 18,75% w/v	Lumax 537,5 SYGNENTA	**0.00040**	R22, R36, R50/53, Xn, N **(25%)**
Terbuthylazine 50% w/v	Terbuthylarine ΝΙΤΡΟΦΑΡΜ 50SC	**0.00077**	R22, R50/53, Xn, N **(25%)**
Dimethoate 40% w/v	DANADIM 40EC Progress ΣΕΓΕ	**0.00028**	R10, R20/22, R43, R51/53, R57, R66, Xn, N **(25%)**
Imidacloprid 20% w/v	IMIDACLOPRID ΥΒΡΙΔΙΑ ΕΛΛΑΣ 20SL	**0.01388**	R22, R36/38, R41, R57 R01, R50/53, R015, R52/53, Xn, N **(10%)**
Gyphosate 36% w/v	Herbolex 36SL ΑΛΦΑ	**0.01737**	R51/53, N **(25%)**

Table 3 presents the results of the first 14 containers analysed by BPI (the analysis of the remaining containers is in progress). The most contaminated containers were found to be those with *Propargite* at 0.64% w/w (threshold limit: 1.0% w/w;) and with *Fluometuron* at 1.51% w/w (threshold limit: 25.0% w/w) (Table 3). It is interesting to notice that the remains measured in another commercial product with the same substance *Propargite* were found to be rather low, at 0.01% w/w (Table 3). The *AgroChePack* traceability system revealed that the contaminated container with *Propargite* was tripled rinsed outside the pilot station while the farmer had delivered it without his ID number on the container. Even though no container was found with remains exceeding the hazardousness threshold limits [9], the two cases identified above suggest that: 1) Containers rinsed without supervision should at least be inspected by the supervisor before been accepted to the system; 2) Containers without farmers' traceability code should be rejected; if identified, the farmer should be issued a strong warning.

Table 3 Hazardousness analysis results of containers from the consolidation station

Commercial Name /Formulation	**Active Ingredient**	**Remaining ingredients**		**Classification R-phrases** (EWC, 2002) / **Hazardous Waste Threshold Limits** *(% w/w)*
		rinsed APPW *(% w/w APPW)*	**rinsed APPW wall scrapings** *(% w/w scrapings)*	
Sulcotrek SC	Terbuthylazine 32.7% w/v Sulcotrione 17.3% w/v	**0.0366**	**0.0010**	R43, R63, R50/53, **N, Xn (1%)**
Stomp aqua CS	Pendimethalin 45.5% w/v	**0.0049**	**0.0450**	R50/53, **N (25%)**
Jaguar 5 EC	Quizalofop-p-ethyl 5% w/v	**0.0014**	**0.0010**	R10, R20/21, R36/38, RO3, R51/53, R41, R22, R37, R50/53, **Xn, N (25%)**
Propargite Farma Chem 57 EC	Propargite 57%w/v	**0.6407**	**0.0320**	R23, R38, R40, R41, R50, R53 **Xn, N (1%)**
Oligor 40 EC	Dimethoate 40% w/v	**0.0057**	**0.0057**	R10, R20, R21, R25, R36/37/38, RO1, RO6, RO11/13/15 **Xn, Xi (3%)**
Assist 10 EC	Cypermethrin 10% w/v	**0.0200**	**0.0144**	R22, R38, R41, R67, R65, R50/53 **N, Xn (10%)**
Record 8/8 EC	phenmedipham 8% w/v desmedipham 8% w/v	**0.0005**	**0.0003**	R20, R22, R36/37, R40, R50/53 N, Xn **(1%)**
Dorian 50 SC	terbuthylazine 50% w/v	**0.0156**	**0.0019**	R22, R50/53, **Xn, N (25%)**
Harness 84 EC	acetochlor 84% w/v	**0.0034**	**0.0224**	R20/22, R37/38, R40, R43, R48/22, RO3, R50/53, **Xn, N (1%)**
Cottonex 50 SC	fluometuron 50% w/v	**1.5093**	**0.0008**	R22, R50/53, **N (25%)**
Lufenuron Farma Chem 5 EC	lufenuron 5% w/v	**0.0066**	**0.0033**	R10, R20, R41, R43, R65, RO3, R50/53, Xn **N (1%)**
Nicogan 4 SC	nicosulfuron 4% w/v	**0.0054**	**0.0021**	R38, R50/53, **Xi, N (20%)**
Bauman 57 EC	propargite 57% w/v	**0.0240**	**0.0056**	T, R10, R21, R23, R38, R40, R41, **Xn, Xi (1%)**
Cyperkill 10 EC	cypermethrin 10% w/v	**0.0115**	**0.0161**	R10, R22, R36/37/38, R65, R67, R50/53, **Xn, N (20%)**

4. CONCLUSIONS

The design principles of an optimized integrated waste management system (*AgroChePack*) for the APPW chain in Europe are presented. The APPW management system, covering all the steps after the usage of the agrochemical until the final receiver, aims to channel the majority of the decontaminated APPW to recycling and the non-recyclable to industry for energy recovery. The pilot implementation of the *AgroChePack* system in Greece has been used to investigate the performance of the APPW management protocols, including decontamination and traceability. The hazardousness analysis of triple rinsed containers collected from the pilot trials confirmed the laboratory experiments results, suggesting that the appropriate application of the triple rinsed technique of containers by trained farmers, under control, ensures their decontamination and their characterisation as non-hazardous waste according to the EWC provisions.

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Scientific review paper

INNOVATIVE MATERIAL AND IMPROVED TECHNICAL DESIGN FOR A SUSTAINABLE EXPLOITATION OF AGRICULTURAL PLASTIC FILM

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Abstract. *The use of plastic material in agriculture has been growing during the last decades thanks to the benefits that it provides in agricultural production. Mainly in protected cultivation plastics play an important role, by performing a passive effect – by protecting the crops from negative weather conditions – and, at the same time, an active effect – by realizing a more favorable environment for the cultivation. On the other hand, the durability of plastic films is strictly related to the modes of use, and in particular to the meteorological and environmental conditions, as well as to the consequences of stresses they are subjected to upon mounting and during their operational life. The possibilities for an improvement in the technical design of the agricultural plastic film, in terms of mechanical strength, radiometric properties and better aptitude of the material for a further recycling are connected with a more close link between its chemical formulation and the engineering performance of the material. The present paper shows, on the basis of an analysis about the main technical achievements in terms of improvement of the engineering properties of agricultural plastic film, a general review about innovative material and new techniques for mechanical recycling of agricultural plastic film.*

Key words: *Agricultural plastic film, technical characteristics, innovative material, radiometric properties, mechanical recycling.*

1. INTRODUCTION

The growing use of plastics in agriculture has enabled farmers to increase their crop production. Today's use of plastics in agriculture results in increased yields, earlier harvests, less reliance on herbicides and pesticides, better protection of food products and more efficient water conservation [15, 42]. According to most recent estimation, the annual consumption in the World of plastic material in the agricultural sector is approximately 5 Millions tons (about 2% of the total plastic production), and it seems to be steadily growing [36, 56]. Protection from hail, wind, snow, or strong rainfall in fruit-farming and ornamentals, together with the realization of a confined airspace with better microclimatic conditions, is the most common case. Plastic films are widely diffused for covering greenhouse, low and medium tunnel, and for soil mulching, while shading nets for greenhouses, or nets for a modification of the microenvironment, are employed as well. Films or nets for the protection against virus-vector insects and birds are also used as standalone covers or in connection with structures for the growing of arboreal cultivation [45].

Agriculture is the most important sector for the application of plastic material as a building component. Within civil and industrial constructions, where other building materials (*i.e.*, bricks, concrete, steel, wood, *etc.*) are more widespread, the use of this material is limited to complementary applications, as window or door frame, as well as flooring, insulating or facing covers. Employed as a covering material in protected cultivation plastic plays a central role, by performing a passive effect – protecting the crops from negative weather conditions – and, at the same time, an active effect, realizing a more favorable environment for the cultivation.

The increasing use of plastic films in protected cultivation calls for further on-depth studies on their durability even in order to contribute to reduce the impact that plastic films in agriculture have on environmental sustainability. The use of plastics in agriculture generates, in fact, serious environmental problems, as those connected with the management of large amounts of post-consume material, mainly in areas characterized by a fragile environment and a marked tourist vocation [10, 15, 44, 45]. With the aim to explore new possibilities of use of plastic material in the agricultural sector, characterized by a lower environmental impact, new materials are currently developed. The main actual technically interesting solutions are those connected with new plastic material characterized by very limited thickness or by longer useful life, with degradable material (mainly bio-based), or through the improvement of recycling techniques, able to transform the post-consume plastic material into a new secondary product [19, 26, 41, 47, 48, 52, 55, 57, 58]. This paper presents, on the basis of an analysis about the main technical achievements on the improvement of the engineering properties of agricultural plastic film, a general review about actual innovative material and new techniques of mechanical recycling of agricultural plastic film.

2. TECHNICAL PROPERTIES OF AGRICULTURAL PLASTIC MATERIAL

The use of plastic materials in protected cultivation is usually limited by an insufficient knowledge of their durability in relation to the typical climatic and environmental conditions of the exposure zone. Recent developments in materials science and technology led to the adoption of a wide range of innovations in the production of new covering materials for greenhouses. Economic and environmental reasons are more and more pushing the industrial producers towards the definition of more thin plastic films, or to the formulation of new materials, that could degrade after their exploitation period [11, 12, 18, 21, 37, 49].

The main technical properties influence the working performance of the plastic material, making it more or less suitable for an agricultural application. These characteristics, moreover, are generally determined by laboratory tests, that are conducted on new material, but a constant exposure to the atmosphere could quickly change some of them. The effect of external factors on the ageing of plastic material could determine a worsening of the mechanical strength, mainly the elasticity modulus and the percentage elongation at break, as well as an influence on the chemical-physical characteristics of the material, with a lowering of the vitreous transition temperature, and finally a general worsening of the spectro-radiometrical characteristics, with a reduction of the transmissivity in the Photosynthetically Active Radiation (PAR) wavelength or strong variation in the Long Infrared wavelength [29, 30, 33, 34, 35].

Under the framework of a general definition of the engineering characteristics that plastic material should perform, the following categories could be pointed out [42]:

*) Physical and chemical properties;
*) Mechanical properties;
*) Spectro-radiometrical properties;
*) Recycling properties;
*) Ageing factors.

2.1. Physical and chemical properties

The most important physical properties that a plastic material should have for its application in protected cultivation are [53]:

-) density;
-) gas and steam permeability;
-) thermal expansion coefficient;
-) thermal conductivity;
-) chemical neutrality;
-) low- and high-temperature stability;
-) melting point;
-) electrostatic properties;
-) surface adhesion of motes.

2.2. Mechanical properties

The most important mechanical properties that a plastic material should have for its application in protected cultivation are [1, 2, 4, 5, 22, 46, 64]:

-) tensile stress at yield;
-) tensile stress at break;
-) percentage elongation at break;
-) tear resistance;
-) elastic limit;
-) Young modulus;
-) compression and bending properties (for rigid plastic material).

2.3. Spectro-radiometrical properties

The most important spectro-radiometrical properties that a plastic film should have for its application in protected cultivation are [59, 66]:

-) transmissivity and reflectivity in the solar band [0 ÷ 3,000] nm, mainly in the PAR wavelength [400 ÷ 700] nm;

-) transmissivity and reflectivity in the Long Infrared band [7,500 ÷ 12,500] nm;

-) transmissivity and reflectivity during stress condition.

2.4. Recycling properties

The most important recycling properties that a plastic material should have for its application in protected cultivation are [14, 43, 60, 61, 62]:
-) the Melt Flow Index (MFI);
-) sufficient mechanical characteristics of the material as new.

2.5. Ageing factors

The factors playing a role in the ageing of a plastic material used for application in protected cultivation are [3, 6, 23, 31, 39, 40]:
-) solar radiation, mainly the UV component;
-) temperature and relative humidity;
-) contact with the oxygen contained in the air and in the rain water;
-) mechanical effect of wind, rain and snow;
-) contact with air dust and atmospheric pollutants;
-) contact with pesticides;
-) contact with the agricultural soil;
-) contact with supporting structural frames;
-) internal stress connected with the installation phase and the external factors.

Among all of these ageing factors, solar radiation, mainly with its Ultra-Violet (UV) component, plays the main role. Based on this assumption, the global energy arriving in that area by the sun is usually accepted in the international technical and scientific literature as a general parameter expressing the global conditions of the area where the plastic material will be installed. This global energy amount, calculated as the integral of the solar power coming from the sun, is expressed in Langleys (Ly), the unit of energy distribution over an area, where:

$$1 \text{ Ly} = 1 \text{ cal/ cm}^2 = 41840 \text{ Joule/m}^2 \qquad (1)$$

3. The sustainable exploitation of agricultural plastic film

The formulation of plastic film is currently based on chemical consideration mainly connected with the composition of the polymer and its additives. The technical aspects about the performance of this material during its working life are usually poorly considered during the design and production phase of these materials [63, 68]. Therefore, plastic materials show a limited life, even if they are produced with considerable quantities of appropriate additives, included into the formulation with the aim to prolong their useful lifetime. All these attempts are usually conduced on a pure empirical basis, without any support of analytical formulation able to constitute a theoretical basis on which the designer of this material could start its analysis.

In this way, main factors able to play a significant role on the final product should be adequately taken into account, as ageing behavior of the material depending on its stress condition and contact with agrochemicals [28, 67] or on the external weather conditions, the influence that the stress condition may play on the radiometrical properties of the film, the role that the Melt Flow Index may play on the further recyclability, as well as the analysis of the results from cyclical mechanical tests.

In the case of degradable film, moreover, the problem of its design is mostly connected with the calculation of the effective working life after which, having concluded its mission, the material can completely degrade into the soil [7, 8, 9, 16, 54].

3.1. Innovative plastic material for agricultural application

Many efforts were devoted during the last decades from the industries to the production of new more efficient plastic film for agricultural application. The main results that were obtained so far may be summarized in the following way:

3.1.1. Traditional plastic film

A traditional film to be used as a covering material in protected cultivation should have mechanical characteristics sufficient for the stretching phase during the installation of the film. Moreover, the percentage elongation at break should be sufficient for the final recovery of the material, at the end of its useful working life. With this aim, the Italian Standard [65] established that a lowering below the limit of 50% of this parameter compared with the value at new is the indicator that the material has finished its working life and has to be removed before that its mechanical characteristics become so poor that its removal and further mechanical recycling could be impossible.

Fig. 1 shows the mechanical characteristics of a thin (25 μm) plastic film – a three-layers co-extruded transparent LDPE-EVA-LDPE added with mineral fillers – that was tested during a project performed at the University of Basilicata under the framework of a EU-funded Programme (POP-FESR) co-funded at Regional level [42].

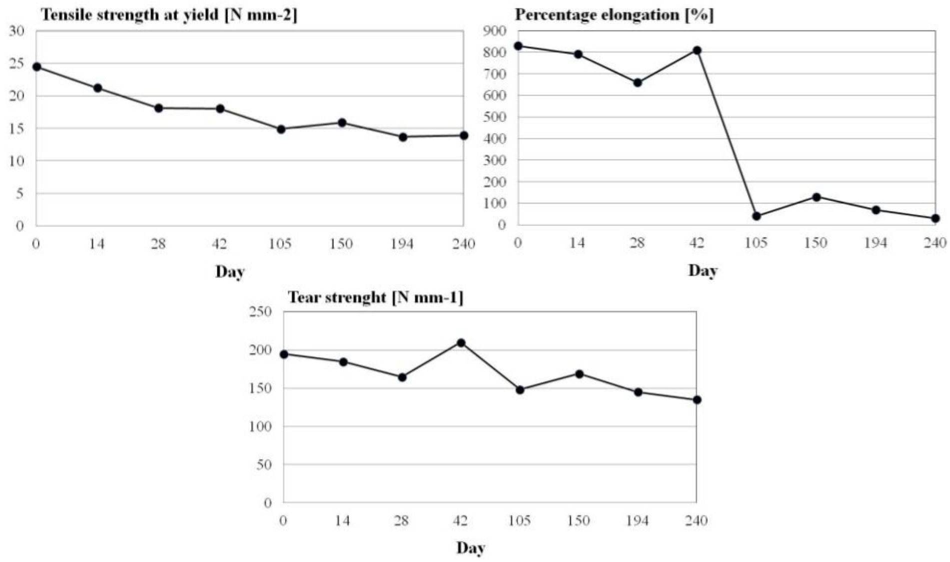

Fig. 1: Evolution in time of the mechanical characteristics (tensile strength, elongation at break and tear strength) of a thin (25 μm) plastic film.

The spectro-radiometrical characteristics that could be performed by an efficient plastic film for protected cultivation should be of high transmissivity in the solar band, mainly in the PAR wavelength [400 ÷ 700] nm, joined with a low transmissivity and quite high reflectivity in the long Infrared wavelength, mainly for those materials that will be employed as soil mulching, low- or medium-tunnels, and soil solarization.

The film should be black or grey in case of mulching. It should be opaque in all the spectral bands of the solar radiation; this characteristic should remain during all the time for the mulching application of the film. Figs. 2 and 3 show the spectro-radiometrical properties over time of the same material that was presented above, a thin (25 μm) three-layers co-extruded transparent LDPE-EVA-LDPE plastic film with mineral fillers [42].

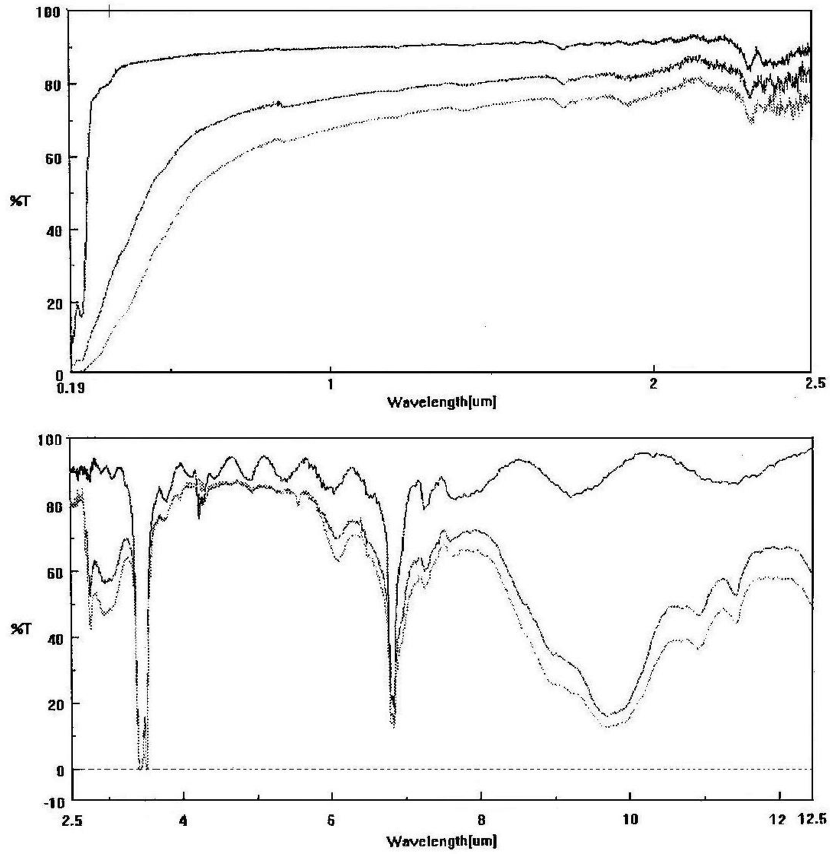

Fig. 2: Radiometrical spectra in total transmission UV-VIS-NIR (upper) and IR (lower) of a thin plastic film. The curves refer to the material new (upper), aged 165 days (medium), aged 270 days (lower) [42].

An interesting application deriving from the laboratory spectro-radiometrical tests [18] is the possibility to obtain an information about the ageing of the material from the evaluation of the Carbonyl Index, defined as [42]:

$$C_I = \varepsilon \frac{A^t - A^0}{S}, \qquad (2)$$

where:

C_I = Carbonyl Index, [%];
A^t = Absorbance of the Carbonyl Index in the range [5380 – 6060] nm at time t, [%];
A^0 = Absorbance of the Carbonyl Index in the range [5380 – 6060] nm at time 0, [%];
ε = Molar absorbance coefficient, m;
S = film thickness, m.

The Carbonyl Index seems an affordable parameter, useful for the evaluation of the ageing level of a plastic film in which the carbonyl groups, even absent in the polymer when new, grow their concentration during the exposition to the external weather factors so modifying their absorbance in the range [5380 – 6060] nm, showing a peak (Fig. 4) in the sub-range [5715 – 5850] nm.

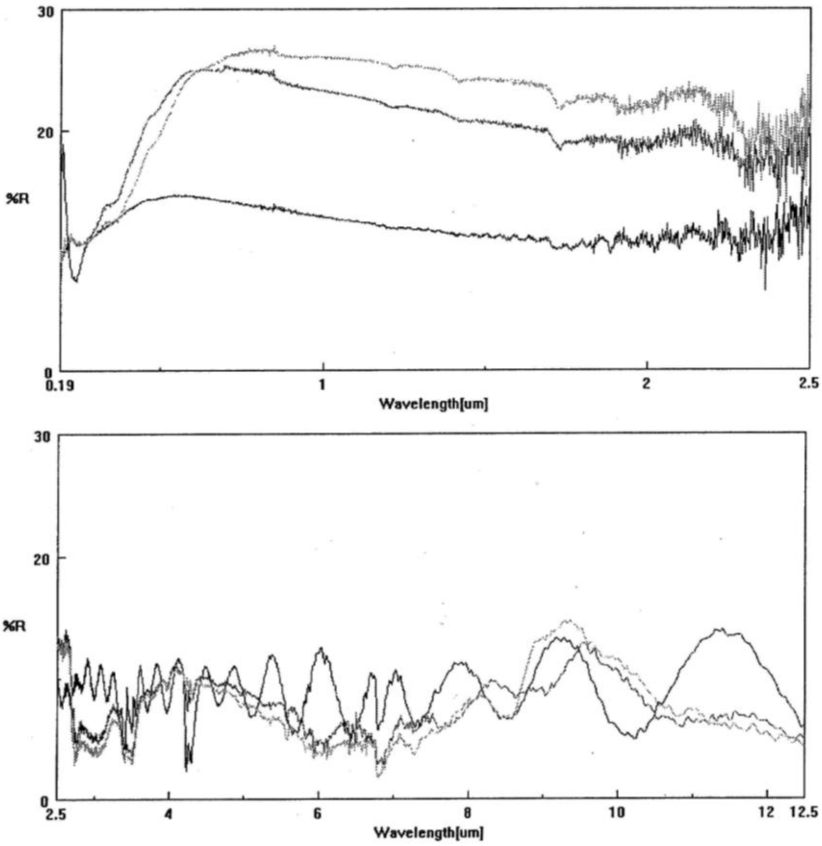

Fig. 3: Radiometrical spectra in total reflection UV-VIS-NIR (upper) and IR (lower) of a thin plastic film. The curves refer to the material new (upper), aged 165 days (medium), aged 270 days (lower) [42].

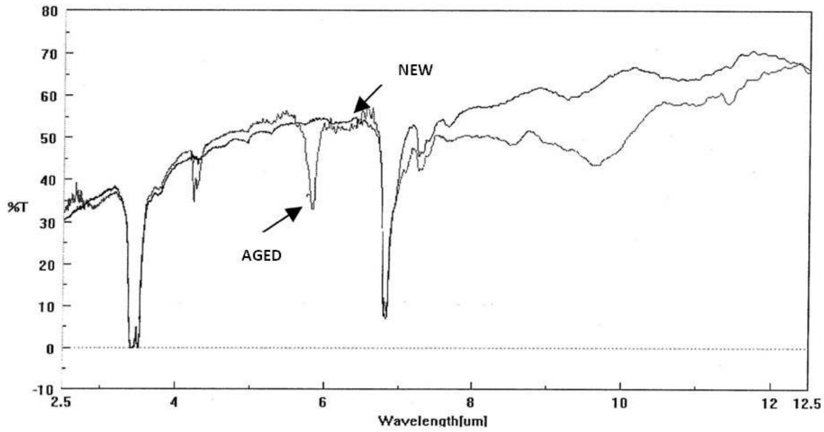

Fig. 4: Spectro-radiometrical diagram of a plastic film before and after ageing. The effect of Carbonyl Index is showed by the arrows [42].

3.1.2. Biodegradable film

Two main categories of biodegradable materials, based on two different concepts, are at the moment under development with the support of intensive research efforts world-wide [8]. In particular, among the materials developed included are fully biodegradable films but also partially biodegradable films or even films of controlled degradation. These latter, currently known as "*oxo-degradable*", are made by blending an additive to provide an oxidative and then a biological mechanism to degrade them. Degradation is a two stage process; first the plastic is converted by reaction with oxygen (light, heat and/or stress accelerates the process but is not essential) to low molecular-weight fragments that water can wet, and then these smaller oxidized molecules are biodegraded, *i.e.* converted into carbon dioxide, water and biomass by microorganisms. The process of biodegradation stops at a certain point, leaving fragments, then being followed by a questionable fate in the soil.

On the other hand, a really "*bio-degradable*" film should be a material that, after its pre-determined working life, can be buried in the soil along with the plant remains in order to be decomposed by microorganisms in to CO_2, water, minerals and a new biomass. This decomposition should leave no toxic substances in the soil or other undesirable by-products and should be fast enough so as not to result in accumulation during the consecutive cultivation periods. The development of new grades of bio-based biodegradable in soil mulching films represents a challenging research area associated with an attractive market [15, 37, 38].

Degradation of a plastic in general, is defined as a detrimental change in its appearance, mechanical and physical properties and chemical structure. It is important to make a distinction between the initiation of the degradation process (commencing in the extruder, at temperatures around 200°C, but controlled) and its manifestation during their useful lifetime. The degradation process may be delayed, enabling a longer useful lifetime of the plastic material, by a special balance of inhibitors engineered to the specific application and to the anticipated life expectancy of the plastic. Heat, ultra-violet radiation and stress can accelerate the degradation process of the material. Degradation of agricultural plastics during their useful lifetime is due to a combination of factors (mainly UV radiation) and may be controlled, to some extent, through the use of appropriate additives [1, 5, 6, 7, 11, 12, 49, 50, 66].

In Fig. 5 the time evolution of the main mechanical characteristics (tensile stress, percentage elongation and tear resistance) is reported for two biodegradable plastic films [42].

Further degradation of the aged agricultural plastic (*i.e.* agricultural plastic waste) following their useful lifetime is directly related to the various disposal options. In any case, degradation of agricultural plastic waste should not result in contamination of the soil and pollution of the environment (including aesthetic pollution) and the agricultural products safety. Describing plastics degradation, measuring it, and controlling it are all issues that are complicated by many technical, chemical and environmental factors [9, 24, 25, 37, 38].

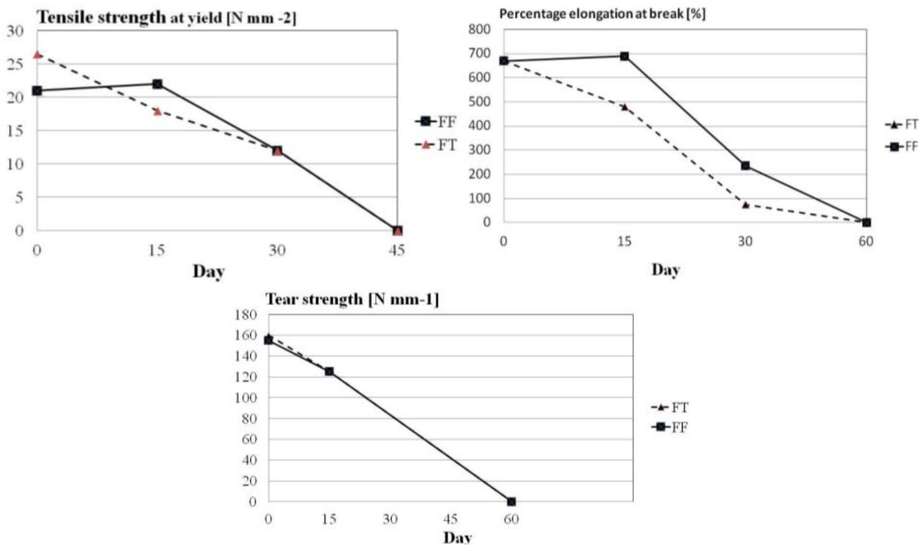

Fig. 5: Time evolution of the mechanical characteristics of two different biodegradable plastic films (initials: FT – FF) [42].

3.1.3. Recycled plastic film

Recycling plastic film with the aim to produce new plastic film is a quite new and not yet well-diffused technical application. In general, this application is possible if the post-consume plastic film has sufficient mechanical properties and a sufficient MFI, and if the plastic waste is well cleaned from other waste (*i.e.*, soil, stones, vegetal residue, *etc.*) that could be frequently present after application in the agricultural sector, mainly as mulching or low-tunnel covers, where the plastic material remains in contact with the agricultural soil [14]. One of the most diffused commercial application is the production of a recycled plastic film that, after the addition of some pigments (*e.g.*, carbon black) could be employed as different material (*i.e.*, black soil mulching, waste bag, *etc.*) [10].

During a recent research performed under the framework of the international EU-funded Project *Labelagriwaste* [48, 69] six recycled materials were tested for mechanical and spectral properties. Results show that, without adding any additive, materials can obtain satisfactory mechanical properties (Table 1) if they are extruded from mixture that consists of 75% of greenhouse covering materials and 25% low tunnel coverings.

The spectral analysis revealed that all tested samples with exception of F4 and Fd5 show a visible light transmittance higher than 80%. It can be concluded that good PAR transmittance can't be expected in the case where HDPE from agrochemical packaging is added to the blends for recycling. Some of the tested materials show good properties for being considered as thermal diffusion film, so, with addition of adequate additives these recycled material could find their implementation in horticulture as mulching or covering materials.

Table 1: Mechanical properties of recycled plastic films [48].

Material Type (mix of post-consume material)	Thickness [μm]	σ_{max} [MPa]	A [%]
F1 – recycled from 50% greenhouse film + 50% low-tunnel film	40	20.60	246.75
F2 - recycled from 75% greenhouse film + 25% low-tunnel film	40	35.71	310.51
F3 - recycled from 25% greenhouse film + 75% low-tunnel film	40	12.54	261.95
F4 - recycled from 25% F1+ 25% F2+ 25% F3+ 25% virgin HDPE	30	29.93	247.69
Fd5 – "*Densified*" recycled film	150	15.41	191.20
Fg5 – "*Granulated*" recycled film	70	18.72	190.87
100% virgin Low Density PolyEthylene (LDPE) film	50	21.74	439.90
100% virgin Ethylene Vinyl Acetate (EVA) film	160	34.54	536.44

The SEM analysis showed that materials were different in their chemical composition but that all were rich in minerals, oxides and chlorides that can influence the worsening of materials properties. The origin of chlorides and some minerals is mostly from the air. Kaolinite and Quartz indicate material contamination by the soil before recycling. Great attention must therefore be paid to collecting, classification, cleaning and storage of collected plastic materials since this can influence the final technical properties of materials [48].

3.2. The technical design of plastic material for agricultural application

Recent developments in materials science and technology led to the adoption of a wide range of innovations in the production of new covering materials for greenhouse. The possibilities of an improvement in the technical design of the agricultural plastic film, in terms of mechanical strength, radiometric properties and a better aptitude of the material for its further recycling, are connected with a closer link between its chemical formulation and the engineering performance of the material.

The main mechanical characteristics could be improved taking into account that their correlation with the exposure time during the working life is not linear. The influence of external weather factors may give initially even an effect of increasing the mechanical properties for a limited short period of time. This effect, usually connected with the creation of possible chemical reticulations, after this "recovery time" usually disappears.

Anyway, the consideration of the mere percentage elongation at break as the unique mechanical indicator of the reaching of the condition (after dropping lower than to 50% of this property of the material as new) for which the material should be considered [18] "*degraded*" and then removed, [6] before losing the mechanical characteristics sufficient for assuring its removal, seems to be questionable. From the mechanical tests, in fact, it is clear that other – even important – characteristics, as the tensile and the tear strength, could remain for a longer time unchanged, so enabling a longer useful lifetime of the material, and then a consequent lower impact on the agricultural environment [8].

The spectro-radiometrical characteristics of a plastic film could be improved by taking into account that the thickness plays an important role on these properties, and that the research of new, thinner material, should anyway cope with the need to assure a thermal effect to the plastic material able to exploit the incoming solar radiation. From this point of view, further research on plastic film and their additives appears as a crucial point for an improvement of this material in protected cultivation.

Mechanical recycling can represent the simplest way of managing plastic waste and, at the same time, obtaining new plastic materials that can be re-used in the agricultural sector. Further investigation should be made on blends optimization and on improving the spectral properties of the new recycled materials.

4. Conclusions

The formulation of plastic film is currently based on chemical consideration based on the composition of the polymer and its additives. The technical aspects about the performance of this material during its working life are usually poorly or totally not considered during the design and engineering phase of these materials. Therefore, plastic materials show a limited life, even if they are produced with considerable quantities of appropriate additives, included into the formulation with the aim of prolonging the useful lifetime of this material.

With the aim to explore how these different aspects could be improved, so that new more efficient formulation of plastic film for agricultural application could be defined, further experimental analysis should be conducted, both in open field and laboratory, aiming at the theoretical formulation of new equations able to predict the useful lifetime of an agricultural plastic film, on the basis of the main meteorological characteristics of the area where this material will be exposed, the working conditions (contact with pesticides, external pollution, *etc.*) and the correlation between radiometrical and mechanical characteristics.

Through natural and artificial ageing experimental tests, this work could be validated, in order to point out the role of the main factors causing degradation of plastic materials in protected cultivation, and draw useful indications to set up forecast models of the evolution of mechanical and radiometric characteristics over time.

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First communication

THE MANAGEMENT OF AGRICULTURAL PLASTIC PACKAGING WASTE: A PILOT EXPERIMENTATION IN SOUTHERN ITALY

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Abstract. In the early sixties started the "green revolution", a phenomenal increase in agricultural productivity worldwide; with it a wide and extensive diffusion of plastic material and a massive use of agrochemicals made their entrance in agriculture. The plastics used at farm level are many and different: film, hard sheet, net, string, tube and agrochemical container. All these plastics become waste and the problem of their disposal cannot be ignored since several studies indicate that most of them are disposed in an illegally way (by burning, burying, dispersion). When the waste are agrochemical containers the problem is more acute because they aren't often rinsed, resulting contaminated with chemical residues. In order to analyze the Italian current situation on this matter the Authors, in the framework of the "Agrochepack" Project, produced a mapping of Agricultural Plastic Packaging Waste (APPW) situation in an area of Southern Italy. This information was took as a basis for the design of a pilot plant that was realized in order to enable pilot tests of APPW disposal. The first indications, as a result of meetings with farmers, showed an increased attention towards the "environmental protection", as shown by the good results that were obtained within the Project.

Key words: *agricultural plastic packaging, waste management, pilot plant, sound disposal, environmental protection*

1. INTRODUCTION

In the early sixties started the “green revolution”, a term used to describe the phenomenal increase in agricultural productivity worldwide. With the green revolution new varieties of plants, called "hybrid", have been introduced, they were more receptive to the nutrients, faster maturation, and they can grow in every season, allowing more crops throughout the year. Besides, an increase in the use of heavy machinery, a wide and extensive diffusion of plastic materials and a massive use of agrochemicals made their entrance in agriculture. Since then, agricultural plastics have replaced traditional materials, such as glass and metal because they often are less costly, safer to use, and improve production efficiency; currently they still continue to have a great deal of attention.

The plastic material generated at farm level strictly depends on ruling of specific agricultural applications, such as films to cover greenhouses and tunnel, hard sheet for greenhouses, film for mulching, rope and strings to sustain crops and trees, harvesting nets or nets for tree protection, film for silage, tubes for different irrigation technique, agrochemical containers and so on [2, 5]. Although with different times, all these plastics become waste and the problem of their disposal cannot be ignored [9].

Several studies indicate that most agricultural plastics are disposed in an illegally way, by burning them on-farm, creating fire hazards, clogging water channels, releasing high levels of polluting emissions, and/or buried and dispersed across the rural landscape [9, 4, 3, 8]. When the agricultural plastics are agrochemical containers the problem is more acute because they aren’t often rinsed, resulting contaminated with chemical residues.

In Italy, as other Countries, an Agricultural Plastic Packaging Waste (APPW) management scheme has not been established yet, so it is necessary to develop appropriate environmentally friendly solutions [7, 6, 1]. In order to analyze the Italian current situation the Authors, in the framework of the “Agrochepack” Project, funded by the European Territorial Cooperation MED Programme (2G-MED09-015), produced a mapping of APPW situation in an area of Apulia Region (Southern Italy), collecting information on cultivations (main species, cultivated areas and their localizations), plastic material and agrochemical products used to estimate Agricultural Plastic Waste (APW) and APPW streams (quantity, temporal and spatial distribution, problems experienced with specific disposal solutions applied) and on farmers' knowledge about the environmental damage caused by poor waste management. This information was took as a basis for the design of a pilot plant that was realized in order to enable experimental tests of disposal of APPW in the Project area.

2. STATE OF THE ART

According to the Italian Law in force (Legislative Decree of the 3th April 2006, n. 152 "Roles on environment” - Annex D) [10], the agrochemical packaging (with residues after their use, or full with expired product) are currently classified as an hazardous waste. They are described by the CER code 15 01 10 - unwashed empty containers for plant protection or agrochemical products. This Law, however, includes in the list of special non-hazardous waste also the agrochemical packaging after "decontamination", without specifying - yet -which is the way to "decontaminate" them.

In order to address this legal gap and satisfy the needs of farms in different Italian provinces, according to article 206 of the same Law n. 152/2006, special "Programme Agreement" between Local Authorities (Municipalities and/or Provinces) and the relevant stakeholders have "standardized" the decontamination procedures, according to the international experience. The guidelines are offered on the understanding that where local laws and regulations are already in place, these must take priority. The guidelines can and should, however, be used in dialogue with the relevant authorities to help shape new laws and regulations and revise existing ones.

The European Crop Protection Association - ECPA’s policy on Container Management Strategies (CMS) consists, essentially, of a fundamental series of commitments to action at the Brussels level and recommendations for action at the national level [11]. These guidelines cover containers for liquid or solid products that are normally diluted with water. All other containers should be disposed according to the instructions on the product label or through agencies licensed for the purpose. These guidelines provide three different options for rinsing:

- Triple rinsing;
- Pressure rinsing;
- Integrated rinsing.

According to many studies, the quantity of dangerous substances that remains in the container after this process, either as residue after rinsing or as product migrated into the plastic, determines the classification of the empty container based on the process and limits described in the EWC. In 1993, the ECPA member companies generated extensive rinsability data on a wide range of packaging and formulations. These data were produced to provide evidence that primary crop protection product packs could be rinsed to leave behind less than 0.01% w/w of the original formulation in the pack. An analysis of data from n.180 rinsed primary crop protection product packs revealed that the average rinsing effectiveness achieved using either manual triple rinsing or integrated pressure rinsing was 0.008%. These findings are supported by other publications that show that crop protection product packs can be rinsed clean below 0.01%.

In 2002, ECPA member companies produced another set of data analyzing the total amount of active ingredient that remains in the container after triple rinsing or pressure rinsing. In addition to the findings that have been investigated in the rinsability study, this also took into account the amount of active ingredient that migrated into the plastic. The results of this study indicated that the total amount of active ingredient in correctly rinsed containers remains well under the threshold for very toxic substances of 0.1% set by the EWC. The amount of respective products sold in Europe is below 3%, with a clear decreasing tendency. For all other products a much larger safety factor exists.

These results clearly indicate that individual containers, even those that contained products with the most critical classification of very toxic, can be classified as non-hazardous after proper rinsing. In particular, triple rinsing is important for the Italian agriculture and it is precisely what the dissemination activities planned and promoted by the Agrochepack Project [12], in order to:

- underline the accountability and responsibility of farmers to have greater attention to the environment and living beings that inhabit it, promoting the reclamation of the containers with the triple rinse;

- give a strategic input to the institutional bodies to improve the systems for collection of empty and reclaimed containers; in this way, farmers wouldn't dispose APPW temporary collected in their farms, burning, burying leaving them in the environment, including water bodies (Fig. 1); contemporary, the traceability would be preserved in all steps.

Fig. 1: APPW abandoned close to water bodies.

3. Material and Method

The Province of Bari, included in the Apulia Region, co-ordinates n. 41 municipalities over an area of 3,821 km^2. Within it, there is the studied area (the so-called "ARO" territory) that includes n. 6 neighbouring Municipalities: Cellamare, Capurso, Noicattaro, Rutigliano, Triggiano and Valenzano.

The APPW management scheme, proposed by University of Basilicata and the Municipality of Cellamare, was concretized into a Pilot Station (Fig. 2) that was designed in order to:

-) enable the pilot tests performed under the Agrochepack Project;

-) enable demonstration activities directed towards politicians, technicians, waste companies, farmers and all the stakeholders interested into this issue.

Fig. 2: The Agrochepack Pilot Station at Cellamare.

In such a way, the Pilot Station conceived, designed and realized under the Agrochepack Project would be the prototypal benchmark to be followed by the Province of Bari for the realization of a full-scale plant for the check and disposal of APPW. In this way, the involvement of the entire ARO could reveal as a key factor for the optimal operation of the Pilot Station, together with the strategic involvement of several relevant local Authorities.

The site identified where the pilot plant was realized lies in the territory of the Municipality of Cellamare, inside a marginal area close to the town. This area is accessible by the provincial road n. SP98, connecting the town of Cellamare with the national highway n. SS100. The pilot plant is situated inside an existing ecological platform equipped for the collection and specific treatments of other special wastes. It works both as local collection station and central consolidation station for the pilot trials.

The collection station has been properly designed to store 100 l bags, until their transport to the final disposal. In particular, the collection station covers an area of about 140 m^2, including 65 m^2 covered with a roof. It is divided into three sub-areas, where different steps of the selection process are implemented. The paving is in concrete with a waterproofing membrane, with a slope suitable to avoid standing water. Galvanized iron net-grid walls of 2.00 m height close the station on three sides.

A cabinet for Personal Protective Equipment (PPE) for the operator (i.e. goggles, filter mask, overalls, gloves and boots for protection from hazardous chemicals belonging to the third category according with the Italian Law D. Lgs. 475/92) and first aid kit store are already present in an area close to the collection station.

The collection station has been concretized in an area very close to the platform for the weighing, in order to limit further movements of mechanical means within the ecological station. At the collection station the operator checks only the quality of the incoming APPW. In particular, the operator:

- chooses randomly the bags from which take containers;
- performs a visual inspection of bag: the bags used have be the ones provided by the scheme, safely closed with plastic straps, with a compiled label; no other material and/or colored-water should be present in the bags;
- takes the containers and checks if they are empty, rinsed and drained.

4. RESULTS AND DISCUSSION

The total considered Agricultural Used Surface is equal to 10,500 ha, of which Arable (cereals and vegetables) and Orchards (including vineyards and olive), respectively of about 1,500 ha (Tables 1-2) and about 9,000 ha (Table. 3).

Table 1: Used Agricultural Area (hectares), per municipalities.

MUNICIPALITY	Arable	Permanent crops	Permanent grassland and Pastures	Total
Capurso	128.85	662.04	3.61	794.50
Cellamare	27.12	300.03		327.15
Noicattaro	820.25	2,554.28	1.60	3.376.13
Rutigliano	410.69	3,672.45	0.40	4.083.54
Triggiano	99.20	1,298.60	0.85	1,398.65
Valenzano	26.66	624.18		650.84
TOTAL	1,512.77	10,624.35	6.46	10,630.81

SOURCE: ISTAT (ITALIAN NATIONAL INSTITUTE OF STATISTIC), THE 6TH AGRICULTURAL CENSUS (2011)

Table 2: Number of farms with arable surface (hectares) and main crops per municipality.

MUNICIPALITY	Total farms	CEREALS		VEGETABLES		ROTATED FODDER CROPS		OTHER HERBACEOUS
		Farm	Area	Farm	Area	Farm	Area	Area
Capurso	202	2	0.20	11	2.59			126.06
Cellamare	45	2	1.95	1	0.02			25.15
Noicattaro	687	18	96.72	59	73.87			649.66
Rutigliano	398	13	66.83	55	34.95	3	8.05	300.86
Triggiano	159	1	1.09	22	5.73			92.38
Valenzano	35	2	3.09	9	6.60			16.97
TOTAL	1,526	38	169.88	157	123.76	3	8.05	1,211.08

SOURCE: ISTAT (ITALIAN NATIONAL INSTITUTE OF STATISTIC), THE 6TH AGRICULTURAL CENSUS (2011)

Since the crops are many and different within the study area, it is possible to assume that the cultivation works are equally distributed throughout the year. Besides, considering that a crop (from establishment to harvest) is frequently subjected to agricultural activities, as pre and/or cover fertilizations, irrigations, pesticide treatments, cropping, etc., it has been very difficult to specify a temporal distribution of cultivation activities. Finally, the same species, but different varieties, were in the n. 6 territories so that the agricultural activities were also different (e.g. to a different time of fruit ripening corresponds, consequently, a different time of their harvesting).

Table 3: Number of farms and areas (hectares) with permanent crops per municipality.

MUNICIPALITY	Total farms	VINEYARD		OLIVE		CITRUS		ORCHARDS	
		Farm	Area	Farm	Area	Farm	Area	Farm	Area
Capurso	712	391	213.46	605	413.05	12	1.39	125	31.73
Cellamare	386	144	86.77	351	201.78	-		63	11.48
Noicattaro	1,403	1,210	2,048.26	490	406.05	5	14.10	147	84.97
Rutigliano	2,844	2,035	3,038.33	763	326.80	16	8.44	671	295.39
Triggiano	1,000	358	350.71	944	885.13	18	3.31	165	52.42
Valenzano	798	90	82.09	769	489.04	17	3.13	211	49.16
TOTAL	7,143	4,228	5,829.62	3,922	2,721.85	68	30.37	1,382	525.15

SOURCE: ISTAT (ITALIAN NATIONAL INSTITUTE OF STATISTIC), THE 6TH AGRICULTURAL CENSUS (2011)

The use of agrochemicals (fertilizers and pesticides) has been different because rain and hailstorm produced, during the testing period, some damages directed on the cultivation, as root rot and/or crack of the fruit, in two of the six municipalities (Noicattaro and Valenzano), promoting another serious damage, i.e. the creation of the access for other adversities, as molds and fungi. Generally, the agrochemical doses were determined on the basis of feelings and traditional experience of the farmer, rather than on the basis of precise information and a calculation rationally carried out. For all that, it has been very difficult to establish how much APPW were really originated and how much of them were management in uncontrolled way.

Regarding the results of the dissemination activities, a remarkable number of farmers coming from the six municipalities of the testing area delivered to the Pilot Station their APPW produced during about 4 months. One of the characteristics of the farming in this area is the quite small dimension of the farm (about 2.00 hectares), whose main crops are vegetables, vineyards and orchards. Moreover, another remarkable aspect of the local farming is the mean age of the farmers: most part of them were older than 60 years in age, so even the ability to cope with the rules of a new environmental procedure reveals quite limited. The farmers involved in the dissemination activities anyway were not able to report the exact amount of the agrochemicals they use.

At the Pilot station of Cellamare were collected and checked by visual inspection about 0.160 tons of APPW equal to n. 1,600 bottles (1 liter). All bags were clean, containing only APPW (no other material or dirty water). About 80 bottles (equal to 5%), taken randomly from the bags, were partially filled with clean water to check if after a quick rinse the water appeared clear. After this control it resulted that only two bottles were not well rinsed.

5. CONCLUSIONS

The first indications, emerged after the start of the Agrochepack Project during year 2011 as a result of the meetings with the farmers, pointed out that most of them didn’t consider as a good environmental practice both the correct recovery and disposal of empty agrochemical containers. The final results of the Project, including the connected training activities over some farmers within the study area, showed how the attention to the "environmental protection" is recently increased. Therefore, farmers would participate actively in the process of recovery of the plastic material and subsequent reuse, being involved in their collection and storage, so performing an active role that could pave the way for a more environmentally friendly Mediterranean agriculture.

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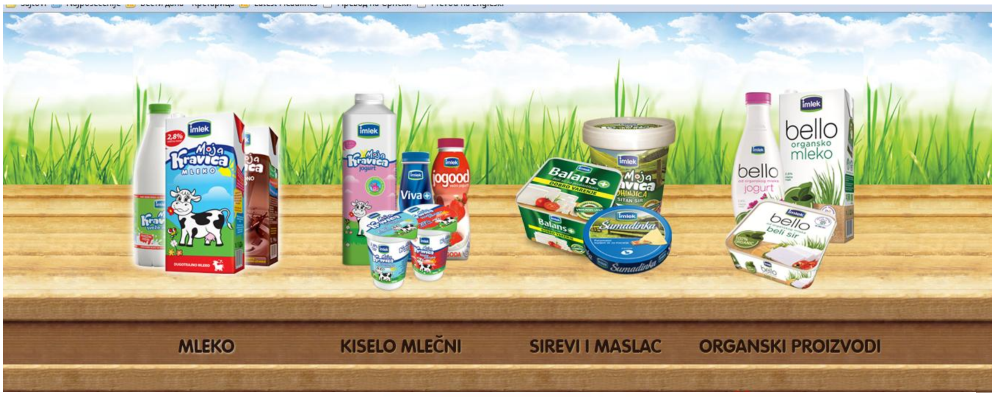

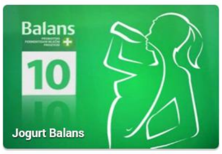

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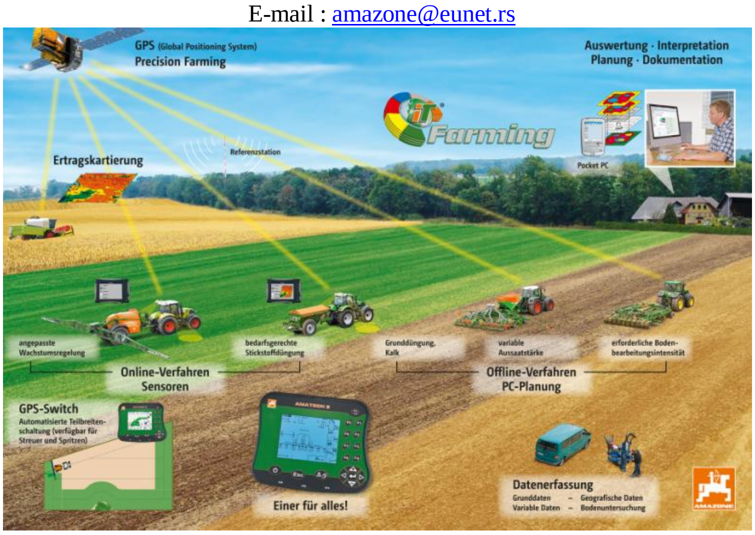

GEA

GEA Farm Technologies

FARME BUDUĆNOSTI – SVEOBUHVATNA REŠENJA

Gde god se mleko proizvodi i gde su životinje bitne, Technologies je pravi izbor. Od 1926. Poznati smo globalni proizvođač za tehničke inovacije, integrisan efektnu higijenu životinja. Omogućavamo proizvođačim troškovno efikasno proizvode mleko visokog standard poznatu muznu opremu, danas je GEA Farm T kompletiran sistemima za stajnjak i štalskom op omogućuje kreiranje sveobuhvatnih rešenja za sve porodičnih farmi ili poljoprivrednih korporacija.

Prateći svetske trendove i potrebe tržišta, razvijamo uvek nova tehnička i tehnološka rešenja. Pomažemo našim klijentima u dostizanju najviših standarda kako u kvalitativnom i higijenskom aspektu tako i u optimizaciji troškova proizvodnje i uvećavanju dobiti.

GEA Farm Technologies nudi kompletan paket usluga potreban proizvođačima mleka. Od projektovanja tehnoloških planova farme, do menadžmenta stada. Brinemo se o Vašoj opremi i garantujemo dugovečnost i pouzdanost u radu. Naša servisna služba Vam uvek stoji na raspolaganju, kao i celokupna paleta proizvoda za higijenu kako životinja tako i opreme i muže. Osluškujući potrebe naših klijenata na svim kontinentima, pomeramo granice tehničkih mogućnosti. Razvili smo koncept „farme budućnosti" sa potpuno automatizovanim sistemima za mužu, ishranu i izđubravanje (tretman stajnjaka) koje usklađujemo sa potrebama investitora.

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