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THE EFFICIENCY OF DIFFERENT MOISTURE AND NUTRITION CONDITIONS IN EARLY POTATO GROWING UNDER DRIP IRRIGATION IN SOUTHERN UKRAINE

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Abstract: The article presents field research results on the effectiveness of different moisture and nutrition conditions at the cultivation of early potato under drip irrigation in southern Ukraine. The scheme of the experiment included the treatment with the complex Mochevyn K as an additional control and different methods and correlation of fertilizers Rlantafol (treatment of tubers before planting, fertilizing, at budding and their combination), as well as different soil moisture conditions (irrigation rates of 100 and 200 m³/ha). Studies have shown that the average yield of early potato without irrigation was 10.44 t/ha. Moisture conditions significantly affected the yield of young tubers – irrigation at a rate of 200 m³/ha provided 21.61 t/ha, whereas reducing the irrigation rate to 100 m³/ha led to a decrease in yield – 19.86 t/ha. The first treatment of planting tubers, treatment of plants at sprouting and during budding provided almost the same yield. The second and the third treatments of plants and tubers did not lead to a significant increase in yield. The highest productivity of potato was provided by Plantafol treatment of tubers and combination of tuber treatment with foliar feeding at mass sprouting phase with a 200 m³/ha irrigation rate for two years: 24.16 and 23.22 t/ha.

Key words: potato seed material, early harvesting, water consumption, tuber treatment, foliar feeding.

Introduction

The issue of fertilizer efficiency in the conditions of each zone needs constant improvement, as evidenced by research conducted in our and other scientific organizations. It is determined that the correct use of fertilizers provides a 40–50% and even higher increase in yield (Bondarchuk and Molotsky, 2007; Yaroshko, 2012; Hamayunova and Iskakova, 2015; M″yalkovs′kyy, 2017). Plant growth

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stimulants are natural or synthetic compounds, which in small doses, at a relatively low cost and ease of use, regardless of weather conditions, allow obtaining additional 3–5 t/ha of tubers from a hectare. (Kuchko and Mytsko, 1995; Romashchenko and Shatkovsky, 2014). The balanced content of a complex of biologically active substances in the preparations determines their high efficiency, due to which the growth of the vegetative mass, root system and tuber formation are accelerated in plants. They promote the active use of nutrients, increase plant resistance to disease, stress and adverse weather conditions (Buhayeva and Snihovy, 2002; Alva et al., 2012).

As you know, the Southern Steppe of Ukraine, according to agrometeorological indicators, is a zone of risky agriculture, so for the cultivation of many crops, it is necessary to use irrigation. In recent years, the method of drip irrigation has become widespread (Kyslyachenko, 2014; Romashchenko and Shatkovsky, 2014). However, some techniques of potato growing technology with this method of watering need further study and refinement. It should be noted that providing plants with all the necessary conditions for their growth and protection from temperature stress, there is a need to use growth regulators, biopreparations and micronutrients when using drip irrigation (Fateyev et al., 2001; Tuchin et al., 2010).

In the South of Ukraine, moisture is the main limiting factor for increasing potato productivity. The hydrothermal coefficient in the Steppe does not exceed 0.9, and in the Southern Steppe – 0.6–0.7. Therefore, without irrigation, it is almost impossible to obtain stable yields. Irrigation softens the microclimate in plantings, and creates conditions for high sustainable yields (Bugaeva and Balashova, 1992; Bugaeva and Balashova, 1997; Fesenko and Kozlovsky, 1997). The effectiveness of irrigation has been proven by numerous studies conducted in the steppe (Boyko, 1976; Balashova, 2010; Romashchenko et al., 2011). According to many researchers (Inst. of Irrigated Agriculture NAAS, Inst. of Potato NAAS (2012) irrigation allows optimizing the processes of moisture exchange of plants, their growth and development, and increases plant productivity by 1.5–4.0 times (Vozhehova et al., 2015). Based on many years of research, the positive effect of drip irrigation on potato yield has been proven (Romashchenko et al., 2006; Romashchenko and Plotnikova, 2006).

However, along with the positive experience of using drip irrigation, there are research results that indicate the negative environmental consequences of the drip irrigation method – the creation of water that is limited to irrigation, the so-called ‘salt bags’, i.e. local areas with soil secondary salinization (Stashuk, 2011). Irrigation of early potatoes, regardless of the irrigation method and the nature of the weather in the years of research, increased the yield of potatoes by 1.3–1.6 times, compared with non-irrigated conditions. The use of drip irrigation on early potatoes can significantly reduce irrigation rates, compared to irrigation by sprinkling and furrows, with a close level of yield (Vozhehova et al, 2015; Kokovikhin and

Golovatsky, 2009). The Institute of Irrigated Agriculture of NAAS studied the regime irrigation for summer planting potatoes. For the conditions of the middle of the year, the irrigation regime of 70–80% field capacity was developed during the period of tuber formation which involved four waterings (irrigation norm of 2000 m^3/ha) (Pisarenko and Golovatsky, 2005). Later, the Institute has updated the data: total water consumption of potato is 2100–4100 m^3/ha by vegetation, an irrigation rate for medium loamy soils during sprinkling is 350–400 m^3/ha, with drip irrigation – 250–280 m^3/ha (Balashova and Yuzyuk, 2016; Kyslyachenko, 2014; Yuzyuk and Balashova, 2017).

Material and Methods

The experimental part of the research was performed on irrigated lands of the Institute of Irrigated Agriculture of NAAS (IIA NAAS), located on the right bank of the Dnieper; the Dnieper district of Kherson in the area of the Ingulets irrigation system.

The soil of the experimental plots is dark chestnut medium-loamy slightly saline on the carbonate loess, typical for the irrigated zone of the South of Ukraine. The content of humus in the arable layer is 2.2%, total nitrogen – 0.17%, mobile phosphorus - 30 mg/kg and exchangeable potassium – 300 mg/kg.

Field capacity in a meter layer of soil (FC) is 21.3%, wilting moisture (WM) – 9.5% by weight of dry soil, structure density – 1.41 t/m^3, pH of the aqueous extract of the arable soil layer is 6.8–7.2. Groundwater lies at a depth of 18–20 m and has virtually no effect on the water-air regime of the zone of active moisture exchange.

The data of the Kherson agrometeorological station located on the territory of the Institute were used to characterize the weather conditions during the research years.

Agrotechnic in the experiment corresponded to the technology of growing potatoes in the South of Ukraine, the requirements of research methods and guidelines for conducting research with potatoes; mathematical processing of experimental data was carried out according to generally accepted methods (Kutsenko et al., 2002; Ushkarenko et al., 2014; Vozhehova et al., 2014).

The task of the research was to establish water consumption of potato plants depending on the conditions of hydration and fertilization with macro- and microelements; to determine the influence of drip irrigation and fertilization with macro- and microelements on the growth, development of potato plants, crop formation; to establish the effectiveness of various irrigation standards and fertilizing; the substantiation of the economic efficiency of technology elements of potato plant watering and feeding for obtaining early potatoes. To solve the tasks in the laboratory of potato biotechnology IIA NAAS during 2014–2015, a field experiment was conducted, the scheme of which is given in Table 1.

Table 1. The scheme of the experiment.

Factor A (soil moisture conditions)	Factor B (plant nutrition)
1. Without irrigation 2. Irrigation rate of 100 m³/ha 3. Irrigation rate of 200 m³/ha	1. Without treatment 2. Treatment with the complex Mochevyn K 3. Treatment of tubers with Plantafol 4. Foliar feeding with Plantafol in the sprouts phase 5. Foliar feeding with Plantafol in the budding phase 6. Treatment of tubers + feeding with Plantafol in the sprouts phase 7. Treatment of tubers + feeding with Plantafol in the sprouts + feeding in the budding phase

The following preparation was used for the experiment:

Mochevyn K is a developer and manufacturer of Limited Liability Company Research and Production Association “Agronaukovets”. Active substances include N (13%), P_2O_5 (0.3%), K_2O (0.15%), microelements (0.1%), succinic acid (0.1%), organic acids, and tricarboxylic acid complex.

Mochevyn K6 accelerates the formation of the root system and the emergence of sprouts. The method of application is the treatment of seed tubers. The consumption for potato is 1 l/t of tubers. Mochevyn K1 stimulates the development of the root system, aboveground mass, strengthens the immune system of plants. The method of application is fertigation, foliar feeding. The consumption potato is 1 l/ha. Mochevyn K2 increases the drought resistance of plants, thickens stems due to the blockade of growth hormones and growth regulators, forms additional sprouts. The method of application includes foliar feeding. The consumption for potato is 1 l/ha (data of Limited Liability Company Research and Production Association “Agronaukovets”).

The treatment with the complex Mochevyn K includes the treatment of tubers before planting of Mochevyn K6, treatment in the sprouts phase of Mochevyn K1, treatment in a budding phase of Mochevyn K2.

Plantafol is a complex water-soluble fertilizer containing microelements for fertilization during the growing season and the treatment of tubers. The treatment of planting tubers implies Plantafol $N_{10}P_{54}K_{10}$ at the rate of 1 kg/t of tubers, and the consumption of a working solution of 20 l/t. The treatment in the sprouts phase implies Plantafol $N_{30}P_{10}K_{10}$ at the rate of 3 kg/ha, and the consumption of a working solution of 250 l/ha. The treatment at the budding phase implies Plantafol $N_5P_{15}K_{45}$ at a rate of 3 kg/ha, and the consumption of a working solution of 250 l/ha.

The study was conducted with a medium-early potato variety Nevska. The area of the first-order plots was 54.9 m^2, the accounting area was 41.2 m^2, the area of the second-order plots was 7.8 m^2, the accounting area was 6.37 m^2. The feeding area was 70 × 32 cm, three repetitions.

Potato in the experiment was planted in spring and harvested after mass flowering (early harvest); the predecessor was winter wheat. Planting density ware recorded in the experiment after emergence and before harvesting; observations of soil moisture were conducted during planting and at the following phases: sprouting, budding, flowering, after harvesting at 0.5-m depth; crop accounting with the definition of its structure was carried after the end of mass flowering.

The following methods were used in the study: field, biometric, measuring-weight, variance and correlation-regression analysis, system analysis and synthesis, economic analysis.

Results and discussion

To provide the specified conditions of moisture before early harvest in 2014, 4 waterings were required at the rate of 200 m³/ha, and 7 at the rate of 100 m³/ha, and in 2015, 5 waterings at the rate of 200 m³/ha, and the rate of 100 m³/ha – 8. The irrigation norm in 2014 at an irrigation rate of 200 m³/ha was 800 m^3/ha, and at 100 was 700 m^3/ha; in 2015 – 1000 and 800 m^3/ha. The average irrigation norm for two years at an irrigation rate of 200 m^3/ha was 800 m^3/ha, and by 100–750 m^3/ha (Table 2).

Table 2. Parameters of the potato irrigation regime for early harvesting in 2014 and 2015.

Humidification conditions	Number of waterings by years, pcs.		Irrigation rate, m³/ha		
			over the years		average for 2014–2015
	2014	2015	2014	2015	
Without irrigation	0	0	0	0	0
Irrigation rate of 100 m³/ha	4	5	800	1000	900
Irrigation rate of 200 m³/ha	7	8	700	800	750

Observations of soil moisture in 2014 showed that in variants without irrigation, the humidity of the 0.5-m layer was at 72% of the field capacity due to precipitation in early May, before budding. Moreover, at the beginning of flowering, soil moisture decreased to 60% of the field capacity, and the plants began to suffer significantly from its lack (Figure 1).

The precipitation between June 1 and 7 somewhat slowed down the drying of the calculated soil layer, but practically did not replenish moisture reserves. The most critical situation occurred during the period of full flowering, when the crop of tubers was intensively formed – soil moisture decreased almost to the humidity of wilting, and water supply of plants was from deeper layers of soil. In the third decade of June, heavy rains slightly improved the water supply to plants, but this almost had no significant impact on plant growth and development and tuber formation. In 2015 the weather was more favorable for potato culture. The humidity of 0.5 m soil layer on the plots without watering, due to precipitation during April, before budding, was at the level of 60% of field capacity. During budding there were heavy rains, which replenished soil moisture to 100% field capacity. And at the beginning of flowering soil moisture was 80–75% of field capacity (Figure 2).

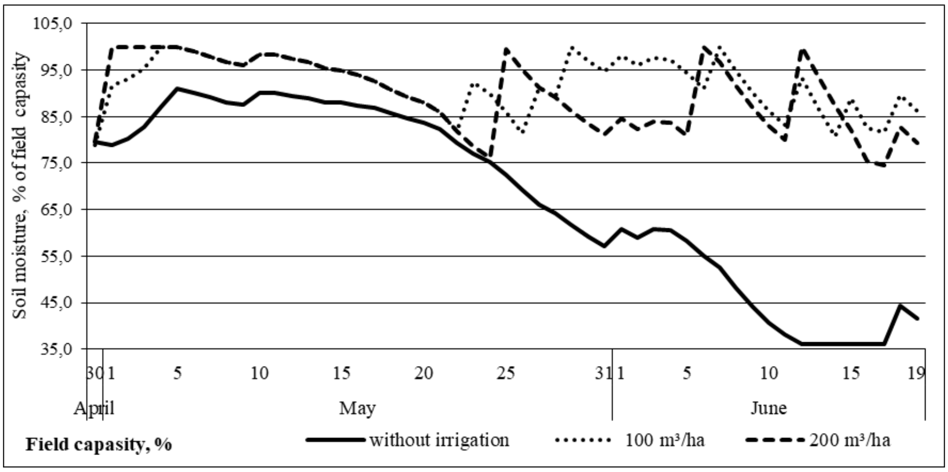

Figure 1. The humidity of 0.5 m of soil layer during the growing season of young potato with different moisture conditions, % of field capacity, 2014.

Conditions prevailing during budding–flowering contributed, on the one hand, to the intensive growth of aboveground mass of plants, and on the other hand, there was not enough of moisture, which led to soil moisture decrease to critical values in the early second decade of June – 41–42% of field capacity, which is badly affected in the process of crop accumulation. The precipitation on June 26–27 somewhat slowed down the drying of the calculated soil layer, but practically did not replenish moisture reserves, and the water supply of plants was due to deeper soil layers with relatively few roots, which had an insignificant effect on plant development and potato tuber crop formation.

Irrigations at a rate of 200 m³/ha provided soil moisture during the budding phase at the level of 81–100% of field capacity, and during flowering not less than 82%. Before harvesting, due to precipitation (June 17–28 in 2014 and June 26–27 in 2015), soil moisture amounted to 77–98% of field capacity. With irrigation at a rate of 100 m³/ha, soil moisture did not decrease less than 82% of field capacity before harvest.

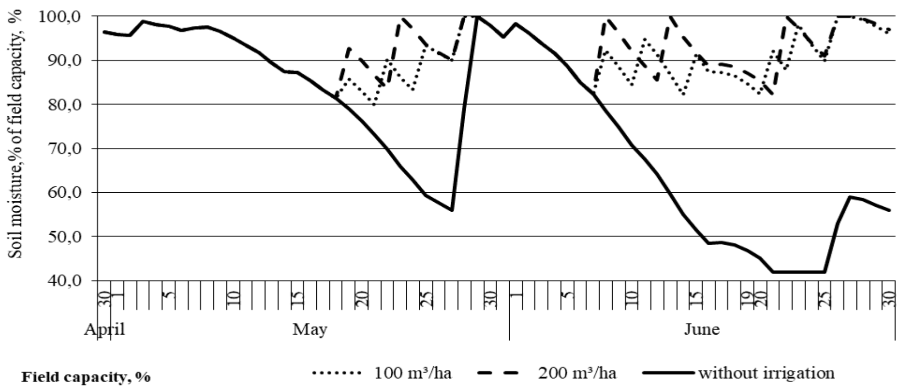

Figure 2. The humidity of the 0.5-m soil layer during the growing season of young potato in different moisture conditions, % of field capacity, 2015.

Potato water consumption without watering from a layer of 0.5 m before early harvesting was 1877 m³/ha, on the average of two years; of which 49.1% were provided at the expense of precipitation, and 50.9% at the expense of soil moisture reserves (Figure 3).

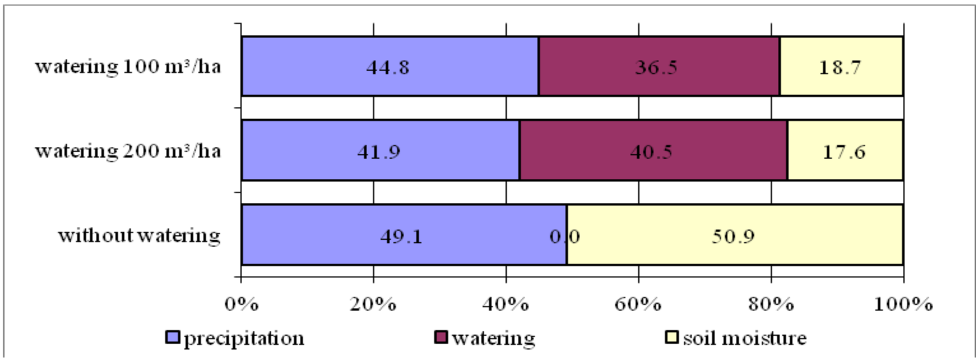

Figure 3. The structure of the water consumption of potato under different conditions of moisture (average for 2014–2015).

The application of irrigation at 100 m³/ha reduced the share of soil moisture to 18.7%, and precipitation provided 44.8% of total water consumption. Increasing the irrigation rate to 200 m³/ha increased the share of irrigation water to 40.5% due to less soil moisture and precipitation.

Over the years of research, the average yield of early potato without irrigation was 10.44 t/ha. Humidification conditions significantly affected the yield of young tubers – watering at 200 m³/ha provided 21.61 t/ha, reducing the watering rate to

100 m³/ha led to a reduction 19.86 t/ha. However, it should be noted that, compared with the option without irrigation, the yield increased by 51.3%.

At the same time, the lowest yield – 9.68 t/ha was recorded in the variant with the treatment with the Mochevyn K complex without irrigation. Plantafol treatment of planting tubers and the treatment of plants during germination and budding without watering provided almost the same yield. The second and the third treatments of plants and tubers did not lead to a significant yield increase. The highest productivity of potato was provided by the treatment of tubers with Plantafol and the combination of tuber treatments and plant treatments during germination with a 200 m³/ha irrigation rate – on average for two years, 24.16 and 23.22 t/ha, respectively (Figure 4).

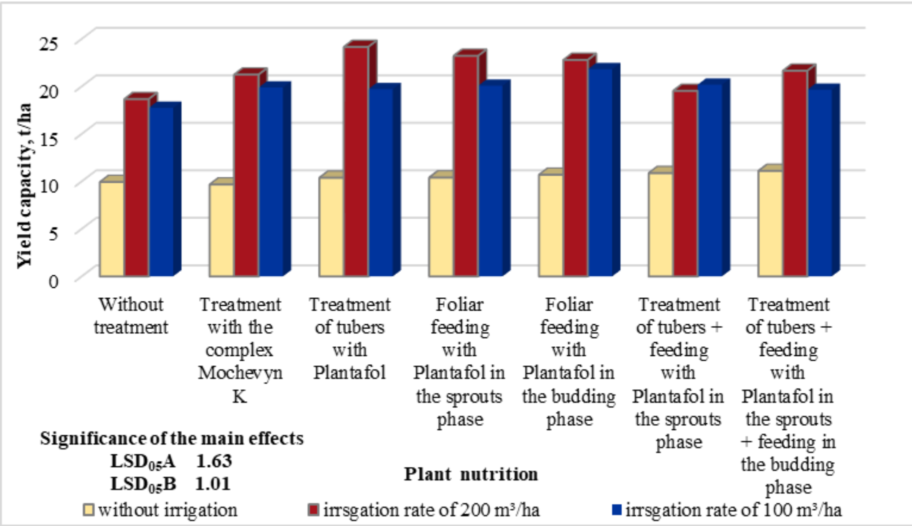

Figure 4. The influence of nutrition and moisture conditions on the yield of potato tubers at early harvest (average for 2014–2015).

It is known that the density of the relationship between the studied factors and the level of yield is estimated by the absolute value of the correlation coefficient (Figure 5).

The results of the correlation-regression analysis indicate a strong positive relationship (r = 0.95, 0.87 and 0.91) in all variants of the experiment. The coefficient of determination showed that the share of the total variation of potato yield was determined by the studied factors (R2 = 0.91, 0.75 and 0.81). In addition, 91%, 75% and 81% of the total fluctuations in potato yield were caused by differences in nutrition and moisture, and the remaining 9%, 25% and 19% – by other factors, which were not taken into account.

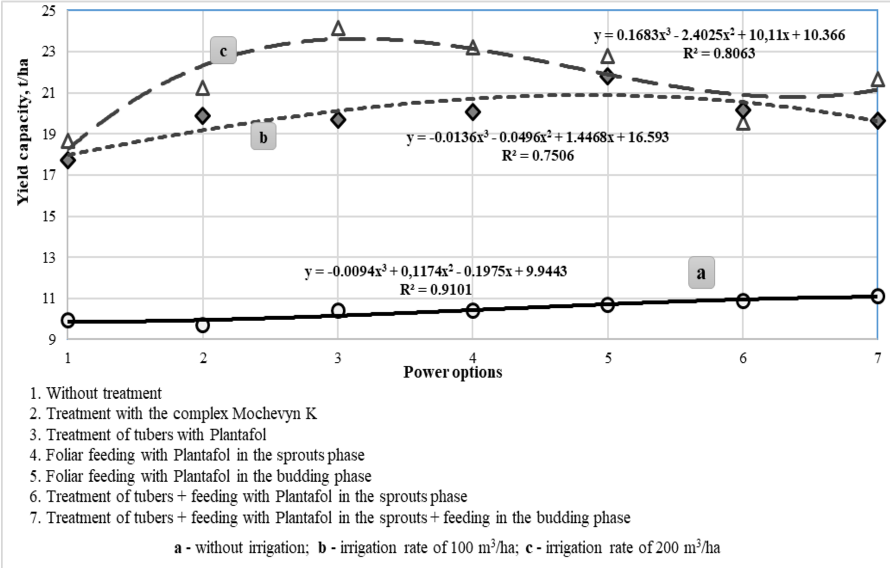

Figure 5. Models of the statistical dependence of the yield capacity from the nutrition and moisture supply (average for 2014–2015).

Given the strong degree of connection ($R^2 = 0.91$) and the variable dependence ($r = 0.95$) between the crop and the studied factors, we had two negative coefficients in the calculated equations of the correlation-regression dependence on the options without irrigation and with the irrigation rate of 100 m^3/ha. This indicates an acute shortage of moisture and a significant shortage of crops in options without irrigation. Due to the treatment of tubers before planting and feeding with Plantafol without irrigation, a slight increase in yield was observed. With the increase of moisture supply by 100 m^3/ha, we observed a significant increase in yield compared to non-irrigated variants, but the trend of the impact of treatment of tubers and plants with macro- and micronutrients on this indicator has not changed. In the equation describing the conditions of sufficient water supply (replenishment of moisture deficit by 200 m^3/ha), a negative coefficient indicates that the second treatment of tubers and plants with Plantafol at the sprouting phase and the budding phase contributed only to a slight increase in yield compared to control without micronutrients.

According to the yield capacity, there was a difference in the efficiency of moisture and irrigation water use (Table 3).

The water consumption coefficient was 194–169 m^3/t of tubers in the variants without irrigation. Its maximum value (194 m^3/t) was recorded in the variant with the use of the treatment with the Mochevyn K complex. The yield herewith was the lowest in the experiment and amounted to 9.68 t/ha, which is 2.6% less than in control. The treatment with Plantafol at sprouting and the budding phase in non-irrigated conditions provided an increase in yield by 11.8%, and reduction of water consumption by 20 m³/t or 10.6%, compared with the control.

Table 3. The efficiency of young potato moisture and irrigation water use depending on plant nutrition in different soil moisture conditions (average for 2014–2015).

Humidification conditions	Plant nutrition	Yield capacity of tubers, t/ha	Water consumption coefficient, m³/t	Efficiency of irrigation water use, kg/m³
Without irrigation	without treatment	9.94	189	-
	treatment with the complex Mochevyn K	9.68	194	-
	treatment of tubers with Plantafol	10.39	181	-
	foliar feeding with Plantafol at sprouting	10.41	180	-
	foliar feeding with Plantafol at budding	10.70	175	-
	treatment of tubers + foliar feeding with Plantafol at sprouting	10.88	173	-
	treatment of tubers + feeding with Plantafol at sprouting + feeding at budding	11.11	169	-
Irrigation rate of 200 m³/ha	without treatment	18.67	119	20.7
	treatment with the complex Mochevyn K	21.24	105	23.6
	treatment of tubers with Plantafol	24.16	92	26.8
	foliar feeding with Plantafol at sprouting	23.22	96	25.8
	foliar feeding with Plantafol at budding	22.79	97	25.3
	treatment of tubers + foliar feeding with Plantafol at sprouting	19.53	114	21.7
	treatment of tubers + feeding with Plantafol at sprouting + feeding at budding	21.65	103	24.1
Irrigation rate of 100 m³/ha	without treatment	17.74	117	23.7
	treatment with the complex Mochevyn K	19.88	104	26.5
	treatment of tubers with Plantafol	19.71	105	26.3
	foliar feeding with Plantafol at sprouting	20.07	103	26.8
	foliar feeding with Plantafol at budding	21.81	95	29.1
	treatment of tubers + foliar feeding with Plantafol at sprouting	20.18	102	26.9
	treatment of tubers + feeding with Plantafol at sprouting + feeding at budding	19.65	105	26.2

The use of irrigation reduced this indicator to 92–119 m³/ha. At the same time, one cubic meter of irrigation water provided 20.7–29.1 kg of tubers. Moisture was best used with applying the irrigation norm of 200 m³/ha and the treatment of tubers with Plantafol – water consumption ratio of 92 m³/t and the maximum yield in the experiment – 24.16 t/ha, which exceeded the control indicator (without treatment, with watering – 200 m^3/ha) by 29.4%. Irrigation water was used most economically when applying an irrigation norm of 100 m³/ha and foliar feeding with Plantafol at the budding phase – 1 cubic meter provided 29.1 kg of tubers, with a water consumption ratio of 95 m³/t; the yield exceeded the control indicator (without treatment) by 4.07 t/ha or 22.9%.

The calculation of economic efficiency has shown that growing young potato without irrigation provides 8.05–15.41K UAH/ha of conditional net profit and 15–35% of profitability (Table 4).

Table 4. The economic efficiency of plant nutrition in different conditions of soil moisture at early potato growing (2014–2015).

Humidification conditions	Plant nutrition	Production costs, K UAH/ha	The cost of potato K UAH/t	Conditional net profit, K UAH/ha	Profitability of production, %
Without irrigation	without treatment	42.48	4.27	12.19	28.7
	treatment with the complex Mochevyn K	44.44	4.59	8.80	19.8
	treatment of tubers with Plantafol	43.93	4.23	13.21	30.1
	foliar feeding with Plantafol at sprouting	43.86	4.21	13.39	30.5
	foliar feeding with Plantafolat budding	43.44	4.06	15.41	35.5
	treatment of tubers + foliar feeding with Plantafol at sprouting	44.88	4.13	14.96	33.3
	treatment of tubers + feeding with Plantafol at sprouting + feeding at budding	53.05	4.78	8.05	15.2
Irrigation rate of 200 m³/ha	without treatment	51.67	2.77	51.01	98.7
	treatment with the complex Mochevyn K	54.77	2.58	62.05	113.3
	treatment of tubers with Plantafol	55.32	2.29	77.56	140.2
	foliar feeding with Plantafol at sprouting	54.76	2.36	72.95	133.2
	foliar feeding with Plantafol at sprouting	53.96	2.37	71.39	132.3
	foliar feeding with Plantafol at budding	53.59	2.74	53.83	100.4
	treatment of tubers + foliar feeding with Plantafol at sprouting	55.50	2.56	63.58	114.6
Irrigation rate of 200 m³/ha	without treatment	50.49	2.85	47.08	93.2
	treatment with the complex Mochevyn K	53.36	2.68	55.98	104.9
	treatment of tubers with Plantafol	52.28	2.65	56.13	107.4
	foliar feeding with Plantafol at sprouting	52.39	2.61	58.00	110.7
	foliar feeding with Plantafol at budding	52.74	2.42	67.21	127.4
	treatment of tubers + foliar feeding with Plantafol at sprouting	53.22	2.64	57.77	108.5
	treatment of tubers + feeding with Plantafol at sprouting + feeding at budding	53.62	2.73	54.46	101.6

The use of irrigation increases production costs in the variant with an irrigation rate of 100 m^3/ha by 0.57–9.3K UAH/ha, with 200 m^3/ha by 2.44–11.39K UAH/ha. However, the cost of potato decreased through increased yields. The net profit increases to 47.08–67.21K UAH/ha and 51.01–77.56, respectively, which provides the profitability of 93.2–127.4% with 100 m^3/ha and 98.7–140% at 200 m^3/ha.

The best economic indicators were formed with the Plantafol $N_{10}P_{54}K_{10}$ treatment at a norm of 1 kg/t with an irrigation rate of 200 m³/ha: production costs were 55.32 K/ha. The cost of potato in this variant was the lowest and amounted to 2.29 K UAH/t, and the highest conditional net profit was 77.56 K UAH/ha and profitability of production – 140.0%.

In different climatic zones, scientists from different countries studied the influence of plant nutrition on the growth, development and yield of potato using the pre-planting treatment of tubers and foliar feeding. Thus, in Belarus, with the use of complex fertilizers and the growth regulator Phenomenelan, they managed to increase yields by 2.6–4.9 t/ha, while improving the quality of tubers. The foliar fertilization of the potato variety Zhukovskaya early by Kristalon brown in the budding phase caused an increase in yield capacity 2.8 t/ha in the Kursk region of Russia. The results of research in Ukraine (Sydorchuk and Kalitsky, 2009; Molots′kyy et al., 2009; M″yalkovs′kyy, 2018;), and in Europe (Van der Saag, 1993; Pomykalska, 1988; Burakov, 2007) indicate that the application of micronutrients for foliar feeding of potato plants helps to increase the yield and quality of tubers. However, with the advent of new forms of preparations of different composition, there is a need to study them in the technology of potato growing (Button and Hawkins, 1958; Laughlin, 1962; Kuisma, 1989; Haider et al., 2012; Jasim et al., 2013; Noaema et al., 2016).

Irrigation creates conditions for the full return of fertilizers, and those, in turn, increase the efficiency of irrigation. For example, according to the results of long-term studies in Moldova, the increase in the yield of tubers from fertilization without irrigation was only 3 centners/ha, against the background of irrigation – 25, from irrigation without fertilizers – 82, from the combined action of fertilizers and irrigation – 10,7 t/ha (Bugaeva and Snihovyy, 2002).

Fertigation, or the application of fertilizers with irrigation water, helps to solve the problem of providing nitrogen, potassium, phosphorus and other elements (Potato grower, 2010). According to research, the effectiveness of applying fertilizers locally during planting and using irrigation water during the growing season is almost the same. The use of fertilizers in this way involves the use of fully soluble or liquid forms. As for the introduction of fertilizers into the soil, their dose is prescribed based on the presence of nutrients in the soil according to the results of the analyses. Feeding is carried out before flowering. Specialized fertilizers for drip irrigation or filtered extracts of combined fertilizers are used

(Pisarenko, 2003). The use of this method of watering in the cultivation of crops allowed increasing yields by 30–50% while saving irrigation water by 3–5 times, mineral fertilizers by 20–40%, energy resources by 50–70%, etc. (Karmanov, 1964; Molyanov and Moiseev, 2003; Koryunenko and Matviyets′, 2004). Based on many years of research, the positive effect of drip irrigation on potato yield has been proven (Ivenin et al., 2012; Shuravilin et al., 2013).

Conclusion

The study of the influence of moisture and nutrition conditions on seed potato growing using drip irrigation showed that the maximum yield – 24.16 t/ha was obtained by treating potato tubers with Plantafol $N_{10}P_{54}K_{10}$ at a norm of 1 kg/t and replenishing the deficit of water consumption by 200 m³/ha. The best use of moisture was recorded – the water consumption coefficient was 92 m³/t, and the lowest cost of potato was 2.29 K UAH/t. The highest conditional net profit was 77.56 K UAH/ha and profitability of production – 140.0%.

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EFIKASNOST RAZLIČITIH USLOVA VLAŽNOSTI I PRIHRANE KOD GAJENJA RANOG KROMPIRA NAVODNJAVANJEM KAP PO KAP U JUŽNOJ UKRAIJINI

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R e z i m e

U radu su predstavljeni rezultati terenskih istraživanja efikasnosti različitih uslova vlažnosti i prihrane pri gajenju ranog krompira navodnjavanjem kap po kap u južnoj Ukrajini. Shema eksperimenta podrazumevala je tretiranje kompleksom *Mochevyn K* kao dodatnom kontrolom i primena đubriva *Rlantafol* u različitim fazama razvoja (tretiranje krtola pre sadnje, đubrenje pri klijanju, pupljenju i njihova kombinacija), kao i različite uslove vlažnosti zemljišta (norma navodnjavanja od 100 i 200 m³/ha). Studije su pokazale da je prosečan prinos ranog krompira bez navodnjavanja 10,44 t/ha. Uslovi vlažnosti značajno su uticali na prinos mladih krtola – navodnjavanjem od 200 m³/ha postignut je prinos od 21,61 t/ha, dok je smanjenje norme navodnjavanja na 100 m³/ha dovelo do smanjenja prinosa – 19,86 t/ha. Prvo tretiranje krtola prilikom sadnje, tretiranje biljaka pri klijanju i tokom pupljenja obezbedili su gotovo isti prinos. Drugo i treće tretiranje biljaka i krtola nije dovelo do značajnog povećanja prinosa. Najveća produktivnost krompira obezbeđena je prilikom tretiranja krtola preparatom *Plantafol* i kombinacijom tretiranja krtola sa folijarnim prihranjivanjem u fazi masovnog klijanja uz navodnjavanje od 200 m³/ha tokom dve godine: 24,16 i 23,22 t/ha.

Ključne reči: semenski materijal krompira, rana berba, potrošnja vode, tretman krtola, folijarno prihranjivanje.

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EFFECTS OF SULPHUR ON THE YIELD, YIELD COMPONENT CHARACTERS AND OIL CONTENT OF OILSEED RAPE

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Abstract: The effects of four sulphur levels: S_0, S_1, S_2 and S_3, including 0, 12, 24 and 36 kg S ha^{-1}, respectively, along with 115 kg N ha^{-1} were studied on yield-related traits of oilseed rape (*Brassica napus* L.). The significant variance of treatments was determined for plant height, yield component characters, seed yield and oil content. The sulphur application significantly increased most of the traits compared to the S_0 level. The S_3 (36 kg S ha^{-1}) treatment led to the highest mean value of plant height (132 cm) which was classified with S_2 (24 kg S ha^{-1}) in the same statistical group. Sulphur had an increasing effect on pods per plant, and it ranged from 92 to 196 for S_0 and S_3 applications, respectively. S_0 and S_1 with 92 and 121 pods per plant were grouped in the same statistical group. In addition, S_2, and S_3 with 165 and 196 pods per plant showed no significant statistical difference. The sulphur application significantly increased seed yield compared to control (S_0 level), and it ranged from 2744 to 3215 kg ha^{-1} in S_0 and S_3, respectively. The average oil contents of 45.69, 46.96, 47.46 and 49.53 % were detected for 0, 12, 24 and 36 kg S ha^{-1}, respectively.

Key words: sulphur, oilseed rape, yield components, oil content.

Introduction

The same as other crops, growth, growing stages, yield component characters, the seed yield of oilseed rape depends upon biotic and abiotic agents (Rameeh et al., 2004). Soil fertility status will vary depending on the type of cultivation and cultivation management. Most soils are usually deficient in organic matter, indicating nitrogen, potassium and phosphorus deficiencies (Malik et al., 2004; Sharifi, 2012). Sulphur (S) is considered the fourth major nutrient along with nitrogen, phosphorus and potassium. Sulphur is important for oilseed rape

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production, and S deficiency frequently constrains canola yield (Jan et al., 2008). Sulphur is essential for the synthesis of compounds such as amino acids, cystine and methionine. In this regard, it activates complex enzyme systems in most plants (Havlin et al., 2005). In addition, sulphur greatly affects rapeseed developmental stages, the most important of which are the increase in protein and oil in oilseed rape (Zhao et al., 1993; Jan et al., 2002; Sattar et al., 2011). Sulphur deficiency mainly leads to a decrease in nitrogen uptake, and the end of this process has an important effect on yield components and finally causes a decrease in seed yield (Fismes et al., 2000; Brennan and Bolland, 2008). In general, characteristics such as total dry matter, harvest index, yield components and grain yield in some rapeseed and mustard genotypes will improve with the increase of sulphur intake (Scherer 2001; Chen et al., 2006; Malhi et al., 2007). About 1.5 kg of sulphur is required to form 100 kg/ha of rapeseed, therefore, to achieve a yield of 2000 kg/ha, approximately 30 kg/ha of sulphur will be required (Jackson, 2000; Kumar et al., 2002; Malhi and Gill, 2002; Kandil and Gad, 2012). As the amount of sulphur consumption increases, the amounts of oil, protein and glucosinolates of canola seeds will also increase (Jackson, 2000; Malhi et al., 2007; Rameeh, 2015). The consumption of sulphur fertilizers leads to an increase in nitrogen efficiency, which improves the amount and, to some extent, the quality of fatty acids. However, the responses of different Brassica species to the absorption of sulphur and the improvement of fatty acids are different (Ahmad and Abdin, 2000; Fismes et al., 2000). The amount of sulphur uptake and transfer in various types of canola cultivars is a function of consumption time, growth stage and plant organs. In this regard, double low varieties of oilseed rape (canola) in comparison with single low varieties of Brassica contain lower sulphur concentrations in seeds and higher sulphur concentrations in pods. In both groups of improved oilseed varieties, including industrial and canola cultivars, a lack of sulphur sources leads to the reduced efficiency of nitrogen consumption (Ceccoti, 1995; Mirzashahi et al., 2010). Low nitrogen uptake efficiency due to sulphur deficiency may lead to soil nitrogen losses (Cheema et al., 2001). According to Abdullah et al. (2010), seeds of Brassica may have a nitrogen-free structural material, in which case part of the structure material is expected to decrease as the grain weight increases, while oil and protein molecules compete to stay in the remaining space (Cheema et al., 2001; Rameeh, 2018). Sulphur plays an essential role in the synthesis of chlorophyll and is also an important component for the synthesis of oil (Brennan and Bolland, 2008; Rehmanuh et al., 2013). Sulphur also plays an important role in the chemical composition of Brassica seeds. Sulphur increases the percentage of seed oil and glucosinolate content (Jan et al., 2002; Subhani et al., 2003; De Pascale et al., 2008). Depending on the external source, sulphur concentrations in different Brassica species, vary between 1 and 16 g/kg in dry matter (Cheema, et al., 2001; Balint and Rengel, 2009).

Due to the importance of the sulphur effect on quantitative and qualitative parameters of oilseed rape, the present experiments were performed to investigate the effect of different sulphur levels on plant height, yield component characters, seed yield, and oil content.

Material and Methods

A field experiment was conducted on the farm located in Abendankash, Sari, Iran (53º 7′ E longitude and 36 º32′ N latitude, 60 m above sea level). The soil was classified as deep loam soil (Typic Xerofluents, USDA classification), and the average percentages of clay, silt, sand and organic matter were 28, 56, 16 and 2.24, respectively, with a pH of 7.3. Soil samples were found to have 45 kg ha^{-1} of mineral nitrogen (N) in the upper 30-cm profile. The field experiment plots received 50 kg P ha^{-1} and 75 kg K ha^{-1}. The seed of the improved canola cultivar Hyola401 was under study. The experiment was conducted in a randomized complete block design with four replications. Seeds were sown at a uniform rate of 4 kg/ha in the rows of each experimental plot. The treatments under study included different amounts of ammonium sulphate (containing 21% of nitrogen and 24% of sulphur) and urea fertilizer (containing 46% of nitrogen): S_0: 250 kg urea ha^{-1}, S_1: 227 kg urea+50 kg ha^{-1} ammonium sulphate ha^{-1}, S_2: 204 kg urea ha^{-1} +100 kg ammonium sulphate ha^{-1} and S_3: 182 kg urea+150 kg ha^{-1} ammonium sulphate ha^{-1}. S_0, S_1, S_2 and S_3 included 0, 12, 24 and 36 kg S ha^{-1}, respectively, and, therefore, all the treatments contained 115 kg ha^{-1} of pure nitrogen. All stage-related measures were performed uniformly for all experimental units. Plant protection measures, including pest and weed control, were also carried out uniformly for each plot. The yield of each experimental plot was determined based on two middle lines and adjusted to kg ha^{-1}. Ten randomly selected plants from each plot were used to measure the following traits: plant height, number of pods per main stem, number of pods per plant, pod length and number of seeds per pod. Random seed samples from each plot were also used to measure 1000-seed weight, oil and protein content. Oil content was detected with the help of nuclear magnetic resonance spectrometry (Madson 1976). The recorded data were analyzed according to randomized complete block design criteria (Steel and Torrie, 1980). SAS software, version 9 (SAS INSTITUTE INC. 2004), was used to analyze the variance and compare the means, and the Excel software was used to draw the graph.

Results and discussion

The significant mean squares indicating significant different effects of treatments (different levels of sulphur) were determined for plant height, pods per main axis, pods per plant, pod length, 1000-seed weight, seed yield, and oil content (Table 1).

Table 1. The randomized complete block (RCBD) analysis of variance for the studied traits.

S.O.V	df	MS							
		Oil (%)	Seed yield (kg ha^{-1})	1000-seed weight (g)	Seeds per pod	Pod length (cm)	Pods per plant	Pods per main axis	Plant height (cm)
Replication		167.3**	1166.8**	2634.1	0.65*	3.25	0.10	3912	0.02
Treatments		67.3*	627.7*	6327.2*	2.85**	41.64*	0.31*	365024**	7.68**
Error		11.3	138.2	781.9	0.15	7.14	0.05	85432	0.41

*, ** Significant at p=0.05 and 0.01, respectively.

As influenced by different sulphur levels, the comparison of plant height means is presented in Table 2 and Figure 1. The sulphur application resulted in a significant plant height increase. The S_3 (36 kg S ha^{-1}) treatment produced the tallest plant (132 cm), which was classified with S_2 (24 kg ha^{-1}) in the same statistical group (Table 2). Sulphur enhances cell division, elongation, and expansion, and it, therefore, tends to increase plant height. The obtained result is in agreement with the results of Ahmad et al. (2006) and Singh and Meena (2004) on mustard. The number of pods on the main axis varied from 27 to 79 in S_0 and S_3, respectively, and the trait tended to increase with the application of sulphur. The sulphur application caused an increase in pods per plant, and it ranged from 92 to 196 in S_0 and S_3, respectively. S_0 and S_1 with 92 and 121 pods per plant belonged to the same statistical group. Also, S_2 and S_3 with 165 and 196 pods per plant were classified in the same statistical group (Table 2).

Table 2. The mean comparison of yield components, seed yield and oil percentage.

Treat-ments	Plant height (cm)	Pods per main axis	Pods per plant	Pod length (cm)	Seeds per pod	1000-seed weight (g)	Seed yield (kg ha^{-1})	Oil (%)
S_0	118.3b	29.6b	92b	5.83c	17.7b	3.84a	2744b	45.69c
S_1	122.4b	48.3ab	121b	6.83b	19.0b	4.00ab	2844ab	46.96cb
S_2	129.3a	63.3ab	165a	7.32b	22.2ab	4.02ab	3190ab	47.46b
S_3	132.2a	79.3a	196a	8.17a	26.0a	4.31a	3215a	49.53a

S_0: 250 kg urea ha^{-1}, S_1: 227 kg urea+50 kg ha^{-1} ammonium sulphate ha^{-1}, S_2: 204 kg urea ha^{-1} +100 kg ammonium sulphate ha^{-1} and S_3: 182 kg urea+150 kg ha^{-1} ammonium sulphate ha^{-1}.

The results are in agreement with those obtained by Chen et al. (2006). Pod length varied significantly among the treatments, wherein the S_3 (36 kg ha^{-1}) treatment showed the highest pod length (Table 2 and Figure 1). Pod length ranged from 5.83 to 8.17cm in sulphur treatments of S_0 and S_3, respectively.

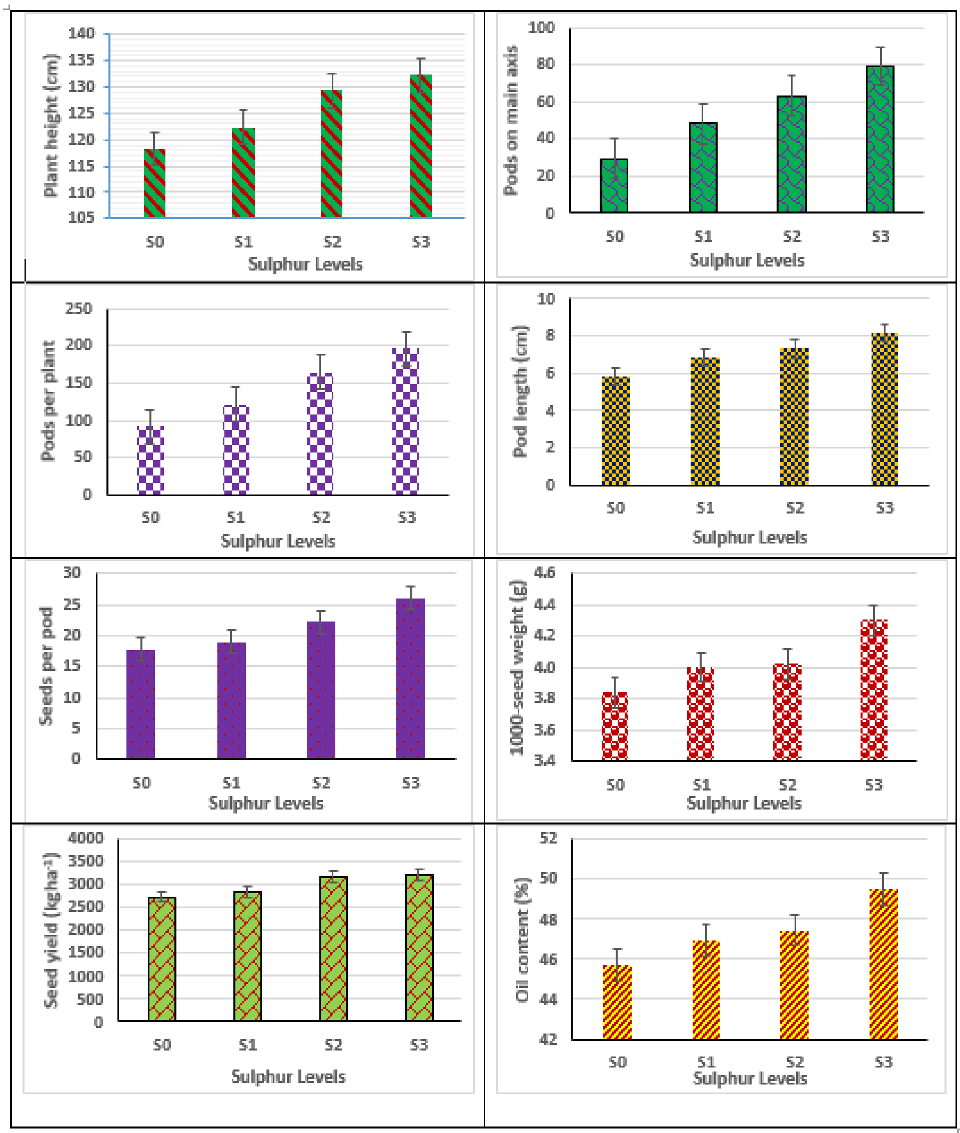

Figure 1. Means of plant height, yield component characters, seed yield and oil content of oilseed rape var. Hyola401 at different levels of sulphur (S_0, S_1, S_2 and S_3 including 0, 12, 24 and 36 kg S ha^{-1}, respectively).

The sulphur application significantly increased 1000-seed weight compared to the S_0 level. Among S treatments, the highest 1000-seed weight (4.31g) was shown by S_3 (36 kg S ha^{-1}), which was on a par with S_1 (12 kg S ha^{-1}) and S_2 (24 kg S ha^{-1}) with 1000-seed mean values of 4 and 4.02 g, respectively. Rapeseed seed yield potential is a function of the main yield components, including the number of plants per unit area, the number of seeds per plant and the 1000-seed weight. The high performance of the treatments related to the application of sulphur may be due to the increase in the reproductive structure of the plant caused by the high capacity of the sink and the high capacity of the transfer of photoassimilates from source to sink (Chen et al., 2006; Malhi et al., 2007). The sulphur application significantly increased seed yield compared to control (S_0 level), and it ranged from 2744 to 3215 kg ha^{-1} in S_0 and S_3, respectively.

The oil content varied from 46.69% to 49.35% and was significantly increased to 36 kg ha^{-1} with the increasing doses of sulphur. Sulphur plays an essential role in the synthesis of chlorophyll and is also an important component influencing the synthesis of oil (Brennan and Bolland, 2008; Rehmanuh et al., 2013). Sulphur also plays an important role in the chemical composition of Brassica seeds, increasing the percentage of seed oil and glucosinolate content (Jan et al., 2002; Subhani et al., 2003; De Pascale et al., 2008).

Conclusion

The sulphur application significantly increased most traits compared to the S_0 (control) level. The S_3 (36 kg S ha^{-1}) treatment produced a high mean value of plant height (132 cm) which was classified along with S_2 (24 kg ha^{-1}) in the same statistical group. Sulphur had an increasing effect on yield component characters, comprising the number of pods on the main axis, number of pods per plant and 1000-seed weight. S_0 and S_1 with 92 and 121 pods per plant were in the same statistical group as well as S_2 and S_3 with 165 and 196 pods per plant. The sulphur application significantly increased seed yield compared to the S_0 level, and it ranged from 2744 to 3215 kg ha^{-1} in S_0 and S_3, respectively. Due to the significantly increasing effect of the maximum level of sulphur application on seed yield and oil content, 36 kg ha^{-1} of S can be recommended for canola production in the region.

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UTICAJI SUMPORA NA PRINOS, KOMPONENTE PRINOSA I SADRŽAJ ULJA ULJANE REPICE

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R e z i m e

Proučavani su uticaji četiri tretmana sumpora: S_0, S_1, S_2 i S_3, uključujući 0, 12, 24, odnosno 36 kg S ha^{-1}, zajedno sa 115 kg N ha^{-1}, na osobine uljane repice (*Brassica napus* L.) povezane sa prinosom. Utvrđen je značajan uticaj tretmana na visinu biljke, komponenate prinosa, prinos semena i sadržaj ulja. Primena sumpora značajno je povećala većinu osobina u poređenju sa dozom S_0. Tretman S_3 (36 kg S ha^{-1}) doveo je do najveće srednje vrednosti visine biljke (132 cm) koja je imala istu statističku značajnost sa S_2 (24 kg S ha-1). Sumpor je imao sve veći efekat na broj mahuna po biljci, i to od 92 do 196 u tretmanu S_0 odnosno S_3. Rezultati u tretmanima S_0 i S_1 sa 92 i 121 mahuna po biljci imali su istu statističku značajnost. Pored toga, S_2 i S_3 sa 165 i 196 mahuna po biljci nisu pokazali značajnu statističku razliku. Primena sumpora značajno je povećala prinos semena u odnosu na kontrolu (doza S_0), i on se kretao od 2744 do 3215 kg ha^{-1} u tretmanima S_0 odnosno S3. Prosečan sadržaj ulja od 45,69, 46,96, 47,46 odnosno 49,53% zabeležen je za 0, 12, 24 odnosno 36 kg S ha^{-1}.

Ključne reči: sumpor, uljana repica, komponente prinosa, sadržaj ulja.

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THE EFFECT OF WEED CONTROL TIMING ON THE GROWTH AND YIELD OF UPLAND RICE (*ORYZA SATIVA* L.)

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Abstract: Weed interference is a major threat to rice production, leading to high yield reduction and reduced profitability. Therefore, field experiments were conducted to evaluate the effect of the different timings of weed control on the growth and yield of upland rice in the 2015 and 2016 cropping seasons. The treatments consisted of periods when the crop was allowed to be weed-infested for the first 3, 6 and 9 weeks after sowing (WAS) and periods when the weeds were controlled for the first 3, 6 and 9 WAS. Two treatments of weed infestation and weed control until harvest were also included as the checks in a randomized complete block design with three replications. In both years, rice grain yields ranged from 0.6 to 0.8 t ha^{-1} in plots kept weed-infested until harvest, and from 3.5 to 3.9 t ha^{-1} in plots kept weed-free until harvest, indicating a 79–83% yield loss with uncontrolled weed growth. Weed infestation for the first 3 WAS did not cause a significant reduction in the growth and yield of rice provided the weeds were removed thereafter. However, the delay in weed control until 9 WAS reduced rice growth and resulted in irrevocable yield reduction. It was only necessary to remove the weeds between 3 and 9 WAS for optimum grain yield, as no significant yield increase was observed in weed control after 9 WAS in both years. This study showed that weed control between 3 and 9 WAS would give the optimum growth and yield of upland rice.

Key words: critical period, grain yield, hoe weeding, weed infestation, weed removal.

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Introduction

Rice (*Oryza sativa* L.) is the most important food crop of the developing world and the staple food of more than half of the world's population (Johnson et al., 2013). It is largely grown by smallholder farmers throughout Africa, where it serves as a major source of food and livelihood to farmers (Takeshima and Bakare, 2016; Kolo et al., 2021). Rice is the second most important staple food in Nigeria, accounting for 10.5% of the average caloric intake (FAO, 2019) and 6% of household expenses (Johnson et al., 2013). It is the most rapidly expanding food commodity both in terms of consumption and production, and, therefore, an important crop for food security, poverty alleviation and income generation for smallholder farmers (Johnson and Ajibola, 2016).

Nigeria is the largest consumer and the second-largest producer of rice in Africa (USDA-ERS, 2019). However, Nigeria currently produces only 5.8 million tons, well below its annual rice requirement of 7.9 million tons, making Nigeria the second-largest importer of rice after China with an average of 2.4 million metric tons a year (Durand-Morat et al., 2019; FAO, 2019). Despite its increased importance and demand, the average rice yield in Nigeria (2.0 t ha^{-1}) is only about half of the global average yield (5.4 t ha^{1}) and far below Egypt's 9.5 t ha^{-1}(Durand-Morat et al., 2019). Numerous factors, including biotic, abiotic and poor cultural practices, are responsible for the low productivity of rice in Nigeria (Rodenburg and Johnson, 2009; Adeyemi et al., 2017; Daramola et al., 2020a). Among these, a biotic factor such as weed interference is particularly one of the principal constraints that have consistently contributed to severe yield losses in rice (Adigun et al., 2017). Weeds compete with rice for growth resources such as water, light, and nutrients (Adeyemi et al., 2017). Weed competition in rice has been reported to result in a high yield reduction of up to 90% (Rodenburg and Johnson, 2009; Adigun et al., 2017).

Smallholder farmers control weeds in rice predominantly by manual hand weeding. However, labour shortage and its high cost are a major constraint. Consequently, the crops are subjected to heavy weed infestation, or the weeds are removed well after the crops have suffered irrevocable yield losses (Waddington et al., 2010; Adigun et al., 2017). Although the use of herbicides is efficient, they do not provide season-long weed control when used alone, and a single herbicide application may not control the entire weed spectrum with diverse physiology, morphology, and time of emergence (Labrada, 2003; Khaliq et al., 2014; Daramola, 2020). In addition, smallholder farmers lack the technical know-how for correct herbicide application. Phytotoxicity and environmental problems that might be induced when herbicides are wrongly applied have made the use of post-emergence herbicides less desirable for smallholder farmers (Labrada, 2003).

There is a stage during the period of crop growth when crops are the most sensitive to weed competition. This period has been regarded as the critical period of weed competition (Knezevic et al., 2003). Weed interference before or after the critical period of weed competition does not result in significant yield loss (Knezevic et al., 2003). Appropriate timing of weed removal during the critical period of weed competition, therefore, will help growers to efficiently use the available resources. In the Philippines, Chauhan and Johnson (2011) reported that the critical period of weed removal in rice was between 18 and 52 days after sowing. Johnson et al. (2004) have reported that to maintain optimum rice yield, a weed removal period between 29 and 32 days in the wet season and between 4 and 32 days in the dry season is required. However, appropriate timing and the duration of weeding required to achieve minimum weed competition and maximum rice yield in Nigerian conditions are still poorly understood. The results reported from other environments might not be applicable to all situations because of differences in soil, weed populations and prevailing weed species. Hence, the objective of this study was to evaluate the effect of different timings of weed control on the growth and yield of upland rice in the forest-savanna transition zone of Nigeria.

Material and Methods

Field experiments were conducted during the cropping seasons of 2015 and 2016 at the Research Farm, Institute of Food Security Environmental Resources and Agricultural Research, Federal University of Agriculture, Abeokuta at latitude 7^{o} 15′ N and longitude 3^{o} 25 ′E in the tropical forest-savanna transition zone of Nigeria. The rainfall pattern at the experimental site is bimodal, with peaks in July and September. During the crop growing season, total rainfalls were 521.3 and 584.1 mm, the mean temperatures were 24.8 °C and 26.7 °C in 2015 and 2016, respectively. The soil at the experimental sites was classified as sandy loam Oxic Paleudulf with 6.7 and 6.9% organic matter, 0.14 and 0.18 cmol kg^{-1} total nitrogen and pH of 6.7 and 6.9 in 2015 and 2016, respectively in the top 20 cm. The site was cleared manually, and plowing and harrowing were done mechanically at a two-week interval. Rice variety (NERICA 2) was sown manually by drilling at the inter-row spacing of 50 cm. Each subplot was 13.5 m^2 in size.

The treatments consisted of periods when the crop was allowed to be infested with weeds for the first 3, 6 and 9 weeks after sowing (WAS) and periods when the weeds were removed for the first 3, 6 and 9 WAS. Two treatments of weed infestation and weed removal until harvest were also included as the checks in a randomized complete block design with three replications. Weed removal was done manually using a hand hoe following the treatments (Table 1).

Data on weed density (No m^{-2}) and dry biomass (g m^{-2}) were taken from a 50-cm^2 quadrat randomly placed at three spots within each plot. Weeds sampled from the quadrat were counted, oven-dried at 70°C until constant weight, and dry biomass was recorded. The weed cover score for each treatment was evaluated by a visual rating based on a scale of 1 to 100%, where the value of 1% represents plots with no weed cover while the value of 100% represents plots that were fully covered with weeds (Kercher et al., 2003; Nikoa et al., 2015). Data on rice were collected from 10 tagged plants within the net plot (9 m^2) at 80 days after planting to determine plant height (cm $plant^{-1}$), number of tillers (number m^{-1}), leaf area and leaf area index (LAI). LAI was calculated following the formula of Watson (1947):

$$LAI = \frac{Leaf\ area\ per\ plant\ (cm^2)}{Ground\ area\ per\ plant\ (cm^2)} \quad (1)$$

The crop vigour score was evaluated by visual rating on a scale of 1–10, where 0 represented plots with dead or least vigorous crops while 10 represented plots with the most vigorous crop (Nikoa et al., 2015). Rice was harvested manually, and grain yield from each plot was recorded at 14% moisture content and expressed in t ha^{-1}. During harvesting, 10 hills were selected within the net plot for measuring panicle length (cm), panicle weight (g), and number of grains per panicle. Data were expressed as mean ± standard deviation (SD) and subjected to analysis of variance (ANOVA) using a mixed model procedure of SAS JAM12. A replicate effect was considered random, whereas the timing of weed control was considered a fixed effect. Means were compared with Tukey's honest significant difference [HSD] ($P \leq 0.05$).

Table 1**.** The details of the period of weed interference treatments.

Treatments	Details
WI3	Weed-infested until 3 WAS
WI6	Weed-infested until 6 WAS
WI9	Weed-infested until 9 WAS
WIH	Weed-infested until harvest
WF3	Weed-free until 3 WAS
WF6	Weed-free until 6 WAS
WF9	Weed-free until9 WAS
WFH	Weed-free until harvest

Results and Discussion

Weed species composition

Sixteen weed species were recorded during the period of crop growth in 2015 and 2016. The weed species comprised eight types of broadleaf weeds, six types of grasses, and two types of sedges (Table 1). The prevalence of both annual and perennial broadleaf weeds and grasses in this study may be as a result of the high disturbance environment that favors them (Menallad et al., 2001; Daramola et al., 2021). However, there were differences in the level of weed infestation between the two years. The level of infestation of some weed species such as *Euphorbia heterophylla, Cyperus rotundus, Panicum maximum, Talinum triangulare* and *Digitaria horizontalis* was moderate in 2015 but increased to a higher level in 2016 (Table 2). Variation in the level of weed infestation between the two years may be attributed to rainfall differences. The rainfall was generally more abundant and evenly distributed in 2016 than in 2015. It has been reported that rainfall affects weed species distribution and their competitiveness within a crop community (Shaidul et al., 2011).

Table 2. Weed species and the level of infestation during the experiment in 2015 and 2016.

Weed species	Plant family	Life cycle	Level of infestation	
			2015	2016
Amaranthus spinosus Linn.	Amaranthaceae	Annual broadleaf	MI[a]	MI
Boerhavia diffusa Linn.	Nyctaginaceae	Perennial broadleaf	MI	HI
Commelina benghalensis Burn.	Commelinaceae	Perennial broadleaf	MI	HI
Euphorbia heterophylla Linn.	Euphorbiaceae	Annual broadleaf	MI	HI
Gomphrena celosioides Mart.	Amaranthaceae	Annual broadleaf	MI	HI
Tridax procumbens Linn.	Asteraceae	Annual broadleaf	MI	HI
Chromolaena odorata (L.) R.M. King and Robinson	Asteraceae	Perennial broadleaf	MI	HI
Talinum triangulare(Jacq.) Willd.	Portulacaceae	Perennial broadleaf	MI	MI
Digitaria horizontalis Willd.	Poaceae	Annual grass	MI	MI
Panicum maximum Jacq.	Poaceae	Perennial grass	MI	HI
Paspalum scrobiculatum (Linn.)	Poaceae	Perennial grass	MI	MI
Axonopus compressus (Sw.) P. Beauv	Poaceae	Perennial grass	MI	MI
Eleusine indica Gaertn.	Poaceae	Annual grass	MI	MI
Cynodon dactylon (L.)Gaertn	Poaceae	Perennial grass	MI	MI
Cyperus rotundus	Cyperaceae	Perennial sedge	MI	HI
Cyperus esculentus	Cyperaceae	Perennial sedge	MI	MI

[a]LI = Low infestation (1–29%); MI = Moderate infestation (30–59%); HI = High infestation (60–90%).

The effect of weed control timing on weed cover score, weed density, and weed biomass

Weed control timing had a significant effect on weed cover score, weed density, and weed biomass in 2015 and 2016 (Table 2). In both years, weed cover score, weed density, and weed biomass increased significantly with an increasing period of weed infestation and *vice versa* with an increasing weed-free period from 3 to 9 WAS (Table 3). Thereafter, there was no significant increase in weed cover, weed density, and weed biomass with an increasing period of weed infestation until harvest (WIH). This was probably due to the lower growth rate of weeds during the final stage of their life cycle and the increased shading by rice which might have limited light penetration for weed germination (Khaliq et al., 2014). This result supports the findings of Satorre and Slaffer (1999), and Daramola et al. (2019a, b), who reported that weed growth and aggressiveness decreased during the final stage of their life cycle. Weed cover score, weed density and weed biomass were similar between plots where weeds were allowed to grow until 3 WAS (WI3) and where weeds were controlled until 9 WAS (WC9). However, allowing weeds to infest the crops until 6 or 9 WAS significantly increased weed cover by 19–160%, weed density by 68–378%, and weed biomass by 46–353%, compared to plots where weeds were controlled until 9 WAS (WC9) in both years (Table 3). In both years, weed control until 9 WAS (WC9) reduced weed density by 69–70% and biomass by 63–67% compared to weed control for 3 weeks only (WC3), while the reduction was 56–57% for weed density and 42–53% for weed biomass when weeds were controlled until 6 WAS. This trend suggests that rapid weed growth was observed between 3 and 9 WAS in both years. This result corroborates an earlier report on the same ecology, which showed that rapid weed growth occurred between 3 and 9 WAS in a study conducted on soybean (Daramola et al., 2019b).

Table 3. The effect of weed control timing on weed cover score, weed density, and weed biomass in 2015 and 2016.

	Weed cover score		Weed density (m^{-2})		Weed dry weight (kg ha^{-2})	
	2015	2016	2015	2016	2015	2016
WI3	53.3 ± 5.7d	33.3 ± 5.6d	21.3 ± 7.5e	23.3 ± 10.2e	15.3 ± 6.6e	19.3 ± 5.0e
WI6	63.4 ± 5.8c	53.3 ± 5.8c	37.0 ± 6.2d	48.0 ± 7.8d	22.6 ± 14.1d	25.0 ± 10.1d
WI9	86.7 ± 5.9a	86.7 ± 5.7a	94.3 ± 11.1a	129.0 ± 26.6a	68.3 ± 10.5a	77.0 ± 6.0a
WIH	87.6 ± 5.7a	88.7 ± 5.8a	92.3 ± 11.1a	129.7 ± 27.6a	69.0 ± 8.8a	76.7 ± 5.9a
WF3	75.3 ± 5.6b	73.3 ± 5.7b	70.3 ± 6.8b	91.0 ± 7.2b	44.7 ± 4.5b	55.0 ± 3.6b
WF6	66.7 ± 5.7c	56.7 ± 5.7c	49.7 ± 5.4c	64.0 ± 5.2c	32.0 ± 3.6c	34.0 ± 2.6c
WF9	53.3 ± 5.8d	33.3 ± 5.6d	22.3 ± 7.5e	27.0 ± 7.8e	15.0 ± 8.5e	20.0 ± 6.2e
SED (df. 6)	6.7	8.6	13.3	14.5	6.5	4.3

WI3 – weed-infested until 3 WAS, WI6 – weed-infested until 6 WAS, WI9 – weed-infested until 9 WAS, WIH – weed-infested until harvest, WF3 – weed-free until 3 WAS, WF6 – weed-free until 6 WAS, WF9 – weed-free until 9 WAS. Means (±SD) in the table followed by the same alphabets are not significantly different ($p \leq 0.05$; Tukey's HSD test).

The effect of weed control timing on the growth, yield components and yield of rice

Weed control timing had a significant effect on the growth and yield of rice in 2015 and 2016 (Table 3). Crop vigour score, plan height, number of tillers, leaf area index, number of grains per panicle, panicle weight, panicle length and grain yield of rice were similar between plots where weeds were allowed to grow until 3 WAS (WI3), and where weeds were controlled until 9 WAS (WC9) or harvest (WCH) in both years (Tables 4 and 5). These results showed that weed infestation for only 3 WAS was not detrimental to rice growth and yield provided the weeds were subsequently removed. This was probably because the weeds were not yet established, and hence could not compete appreciably with the crop at this time. Only grass weed seedlings and few annual broadleaf weeds were present at this initial stage of crop growth, and these were small and physiologically immature to offer significant competition to the crop seedlings. This result is contrary to the report of Toure et al. (2013) that weed infestation from 14 days after sowing was detrimental to rice grain yield in a study conducted in Mali where the main infesting weed species were *Dactyloctenium aegyptium*, *Digitaria loniflora* and *Acanthospermum hispidum.* The crop response to periods of weed interference between the two locations could be due to contrasting rice varieties, weed flora, soil moisture regimes and prevailing climatic conditions. However, the result of this study corroborates earlier investigation in the same ecology, which showed that weed infestation for the first three weeks did not cause a significant reduction in the crop growth and yield of rice (Adeyemi et al., 2017) and soybean (Daramola et al., 2020b, c).

Table 4 The effect of weed control timing on rice growth parameters in 2015 and 2016.

	Crop vigour score		Plant height (cm)		Number of tillers m^{-2}		Leaf area index	
	2015	2016	2015	2016	2015	2016	2015	2016
WI3	8.7 ± 0.5a	9.3 ± 0.6a	117.4 ± 8.5a	122.0 ± 6.5a	43.5 ± 2.5a	46.1 ± 3.6a	0.36 ± 0.07a	0.30 ± 0.06a
WI6	4.7 ± 1.5d	4.3 ± 0.6d	83.6 ± 16.5c	70.5 ± 11.0c	18.4 ± 5.5c	19.4 ± 2.6c	0.23 ± 0.08c	0.21 ± 0.06c
WI9	3.3 ± 1.1e	2.3 ± 0.7e	53.2 ± 2.5d	51.3 ± 7.1d	21.1 ± 5.0c	17.7 ± 5.0c	0.12 ± 0.01d	0.12 ± 0.01d
WIH	3.0 ± 0.6e	2.3 ± 0.5e	51.3 ± 2.0d	42.7 ± 7.1d	21.3 ± 7.7c	17.5 ± 3.4c	0.12 ± 0.01d	0.11 ± 0.01d
WF3	6.0 ± 0.6c	5.7 ± 0.5c	96.6 ± 16.5b	79.4 ± 20.9b	31.1 ± 3.4b	27.6 ± 7.6b	0.24 ± 0.04c	0.22 ± 0.06c
WF6	8.0 ± 0.7b	7.0 ± 0.6b	94.6 ± 11.0b	82.4 ± 13.3b	43.3 ± 4.9a	43.9 ± 3.3a	0.30 ± 0.04b	0.26 ± 0.07b
WF9	9.3 ± 0.6a	9.7 ± 0.7a	118.7 ± 9.5a	124.3 ± 5.6a	42.7 ± 1.1a	44.6 ± 2.5a	0.30 ± 0.07a	0.30 ± 0.06a
WFH	9.3 ± 1.7a	9.6 ± 0.6a	116.1 ± 8.5a	120.6 ± 7.7a	45.3 ± 1.7a	46.2 ± 1.7a	0.35 ± 0.06a	0.31 ± 0.06a
S.E.D (df. 7)	0.9	0.4	7.5	8.2	3.0	3.3	0.04	0.03

WI3 – weed-infested until 3 WAS, WI6 – weed-infested until 6 WAS, WI9 – weed-infested until 9 WAS, WIH – weed-infested until harvest, WF3 – weed-free until 3 WAS, WF6 – weed-free until 6 WAS, WF9 – weed-free until 9 WAS, WFH – weed-free until harvest. Means in the table followed by the same alphabets are not significantly different ($p \leq 0.05$; Tukey's HSD test).

In both years, delaying weed control from 3 to 9 WAS (WI3, WI6 and WI9) resulted in a significant reduction in all the growth and yield parameters compared to crops kept weed-free until harvest (WCH). The number of tillers was reduced by

59% in 2015 and by 58% in 2016 when weeds were allowed to grow until 6 WAS (WI6) compared to crops kept weed-free until harvest (WCH). A further delay in weed control from 6 WAS (WI6) to harvest (WCH), however, did not result in a significant reduction in the number of tillers in both years (Table 4). The corresponding yield loss for a 3-week delay in weed control between WI6 and WI9 was 13% in 2015 and 19% in 2016 (Table 5). Higher yield reduction observed with increasing the period of weed infestation in 2016 than in 2015 in this study is a reflection of the competitive advantage of C4 weeds such as *Euphorbia heterophylla, Cyperus rotundus, Panicum maximum, Talinum triagulare* and *Digitaria horizontalis*, which were more abundant in 2016 than in 2015. These weed species probably took advantage of the higher amount of rainfall recorded in 2016 compared to 2015. Procopio et al. (2004) have earlier reported that C4 weeds exhibit enhanced metabolism, which confers them a higher efficiency in water use and net photosynthesis than rice which is a C3 plant.

Table 5. The effect of weed control timing on yield and yield attributes of rice in 2015 and 2016.

	Number of grains per panicle		Panicle weight (g)		Panicle length (cm)		Grain yield t ha^{-1}	
	2015	2016	2015	2016	2015	2016	2015	2016
WI3	206.7 ± 14.4a	225.6 ± 17.3a	58.3 ± 13.5a	53.3 ± 19.5a	23.9 ± 1.3a	25.7 ± 1.2a	3.9 ± 0.2a	3.4 ± 0.7a
WI6	167.4 ± 29.0b	149.7 ± 36.8c	32.0 ± 6.2c	38.0 ± 6.5c	20.5 ± 2.6b	21.7 ± 1.8b	2.0 ± 0.2d	1.5 ± 0.1d
WI9	69.0 ± 12.5d	59.9 ± 16.3d	19.3 ± 5.5d	18.0 ± 3.4d	15.6 ± 5.3c	12.5 ± 1.0c	0.9 ± 0.4e	0.7 ± 0.2e
WIH	66.0 ± 12.6d	59.7 ± 14.7d	17.0 ± 2.6d	16.3 ± 2.0d	15.7 ± 3.1c	12.5 ± 0.8c	0.8 ± 0.3e	0.6 ± 0.2e
WF3	143.7 ± 8.1c	145.9 ± 11.4c	35.6 ± 1.5c	30.7 ± 5.1c	21.1 ± 2.1b	21.1 ± 1.3b	2.5 ± 0.9c	2.3 ± 0.5c
WF6	164.0 ± 8.8b	164.0 ± 9.6b	49.7 ± 11.9b	45.3 ± 16.6b	24.1 ± 1.6a	25.8 ± 1.6a	3.4 ± 0.9b	2.8 ± 0.6b
WF9	219.6 ± 19.2a	219.6 ± 21.8a	59.7 ± 12.9a	55.3 ± 18.5a	23.9 ± 1.8a	25.6 ± 1.7a	3.8 ± 0.8a	3.4 ± 0.7a
WFH	227.9 ± 20.7a	225.9 ± 20.0a	57.6 ± 12.5a	55.0 ± 20.2a	24.1 ± 1.9a	26.7 ± 0.9a	3.9 ± 0.4a	3.5 ± 0.6a
S.E.D (df. 7)	8.2	10.5	6.8	8.3	2.5	2.3	0.4	0.3

WI3 – weed-infested until 3 WAS, WI6 – weed-infested until 6 WAS, WI9 – weed-infested until 9 WAS, WIH – weed-infested until harvest, WF3 – weed-free until 3 WAS, WF6 – weed-free until 6 WAS, WF9 – weed-free until 9 WAS, WFH – weed-free until harvest. Means in the table followed by the same alphabets are not significantly different ($p \leq 0.05$; Tukey's HSD test).

Allowing weed infestation between 3 and 9 WAS (WI3 and WI9) and subsequently controlling the weeds did not alleviate growth and yield depression of the crop compared to the crop weed-infested until harvest (WCH). The period between 3 and 9 WAS was the period of the most rapid increase in weed density and biomass. Hence, the significant reduction in growth and yield observed may be due to increased weed competition for growth resources. The previous findings of Khaliq (2012) have shown that there is limited use of resources (moisture, light and nutrients) for crop growth and productivity due to an increase in weed competition. Other reports on the Nigeria forest-savanna also revealed a significant yield reduction in crop growth of soybean (Daramola et al., 2019a) and cowpea (Adigun et al., 2018) due to weed infestation between 3 and 9 weeks. The result of this study showed that a further delay in the weed control from 9 WAS (WI9) to harvest (WIH) did not result in a significant reduction in all the growth and yield parameters in both years (Tables 3–5). This was possibly because weed density and biomass did not increase significantly during this period. Moreover, the weeds were less aggressive due to their lower growth rate during this period. Hence, their presence was not detrimental to rice growth and yield. This result supports the findings of Khaliq et al. (2014), who have reported that rice is less vulnerable to weed competition during its late phase of growth.

In both years, crop vigour score, plant height, number of tillers, leaf area index, number of grains per panicle, panicle weight, panicle length and grain yield of rice increased significantly where plots were kept weed-free until 9 WAS (WC9) compared to 3 WAS and 6 WAS only (WC3 and WC6). However, these growth and yield parameters did not differ significantly between plots where weeds were controlled until 9 WAS (WC9) and where weeds were controlled until harvest (WCH) in both years. Weed control until 9 WAS (WC9) increased rice grain yield by 52% compared to weed removal until 3 WAS (WC3) and by 15–25% compared to weed removal until 6 WAS (WC6) in both years. No significant yield increase was observed in weed control after 9 WAS in both years. Weed density and biomass did not increase significantly beyond 9 WAS in weed-infested plots, and the weeds at this period probably reduced competition with the crop due to the shading effect of rice canopy. Hence, their subsequent control was not expected to improve crop growth and yield. This result has corroborated the report of Ekeleme (2009) that there is little or no benefit of subsequent weed control after 9 weeks of crop growth provided the crops were initially kept weed-free.

Conclusion

The results of this study have shown that rice can tolerate weed infestation initially for the first 3 weeks and that the minimum period that it should be kept weed-free was 9 WAS without causing any significant reduction in growth and yield compared to crops kept weed-free until harvest. Hence, weed removal between 3 and 9 weeks after sowing was sufficient to maintain maximum grain yield. This period coincided with the period of maximum weed growth and the most significant reduction in crop vigour, plant height, number of tillers and leaf area index due to weed interference. Therefore, weed removal between 3 and 9 WAS is recommended for effective weed control, optimum growth and higher yield of upland rice.

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UTICAJ VREMENA SUZBIJANJA KOROVA NA RAST I PRINOS PLANINSKOG PIRINČA (*ORYZA SATIVA* L.)

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Rezime

Zastupljenost korova predstavlja glavnu pretnju za proizvodnju pirinča, što dovodi do visokog smanjenja prinosa i smanjene profitabilnosti. Zbog toga su sprovedeni terenski eksperimenti kako bi se procenio efekat različitog vremena suzbijanja korova na rast i prinos planinskog pirinča tokom 2015. i 2016. vegetativne sezone. Tretmani su se sastojali od perioda kada je bilo dozvoljeno da usev da bude zakorovljen tokom prve 3, 6 i 9 nedelja nakon setve, i perioda kada je korov suzbijan prve 3, 6 i 9 nedelja nakon setve. Dva tretmana zakorovljavanja i suzbijanja korova do žetve bila su takođe uključena kao kontrole u potpuno slučajnom blok dizajnu sa tri ponavljanja. Tokom obe godine, prinosi zrna pirinča kretali su se od 0,6 do 0,8 t ha^{-1} na parcelama koje su bile zakorovljene do žetve, kao i od 3,5 do 3,9 t ha^{-1} na parcelama bez korova do žetve, što ukazuje na gubitak prinosa od 79% do 83% pri nekontrolisanom rastu korova. Zakorovljenost tokom prve 3 nedelje nakon setve nije prouzrokovala značajno smanjenje rasta i prinosa pirinča pod uslovom da je korov nakon toga uklonjen. Međutim, kašnjenje u suzbijanju korova do 9 nedelja nakon setvene smanjilo je rast pirinča i dovelo do nepovratnog smanjenja prinosa. Bilo je samo neophodno da se ukloni korov između 3 i 9 nedelja nakon setve, kako bi se postigao optimalni prinos zrna, jer nije primećen značajan porast prinosa pri suzbijanju korova nakon 9 nedelja posle setve tokom obe godine. Ova studija je pokazala da bi suzbijanje korova između 3 i 9 nedelja dovelo do optimalnog rasta i prinosa planinskog pirinča.

Ključne reči: kritični period, prinos zrna, okopavanje, zakorovljenost, uklanjanje korova.

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MOGUĆNOST DEZINFEKCIJE SEMENA KORIJANDERA ETARSKIM ULJEM PITOME NANE

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Sažetak: Ispitivanje zdravstvenog stanja semena ima za cilj osiguranje dobijanja zdravog useva i sprečavanje širenja biljnih bolesti upotrebom zaraženog semena. Potreba za proučavanjem i primenom etarskih ulja i biljnih ekstrakata u cilju zaštite semena se povećava i ona sve više dobijaju na značaju. Korijander (*Coriandrum sativum* L.) je jednogodišnja zeljasta, aromatična, začinska i lekovita biljka iz familije Apiaceae, poznata po semenu karakterističnog i prijatnog mirisa. U humanoj medicini korijander ulazi u sastav raznih lekova za lečenje organa za varenje. Najčešći i najznačajniji prouzrokovači oboljenja semena korijandera su fitopatogene gljive i bakterije. Cilj ovog istraživanja bio je da se ispita zdravstveno stanje semena korijandera i mogućnost dezinfekcije etarskim uljem pitome nane (*Mentha* x *piperita*). Zdravstveno stanje semena ispitano je standardnom laboratorijskom metodom na filter papiru, a mogućnost dezinfekcije potapanjem semena u različite koncentracije (1, 2, 5 i 10%) etarskog ulja pitome nane. Sastav etarskog ulja određen je gasnohromatografskom analizom. Nakon sedam dana inkubacije u vlažnoj komori na sobnoj temperaturi, na osnovu prisustva simptoma, makroskopskim i mikroskopskim pregledom i izolacijom gljiva na hranljivu podlogu krompir dekstrozni agar, utvrđeno je da su na/u semenu prisutne patogene gljive iz roda *Alternaria* sekcija *Alternaria*. Potapanje zaraženog semena u rastvore etarskog ulja pitome nane smanjilo je zaraze tretiranih semena. Najveću inhibiciju zaraze 69,33%, odnosno 58,93% kada se izuzme delovanje emulgatora, ispoljilo je ulje primenjeno u koncentraciji od 5%. Uočena je stagnacija u inhibiciji sa daljim povećavanjem koncentracije ulja. Rezultati ovih ispitivanja ukazuju na mogućnost dezinfekcije semena korijandera etarskim uljem pitome nane s ciljem zaštite od bolesti prouzrokovane gljivom *Alternaria* sp.

Ključne reči: zdravstveno stanje semena, seme korijandera, etarsko ulje pitome nane, *Alternaria* sp.

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Uvod

Korijander (*Coriandrum sativum* L.) je jednogodišnja zeljasta, aromatična, začinska i lekovita biljka iz familije Apiaceae. Poreklom je iz severne Afrike i istočnog Sredozemlja. U narodu je poznata i kao paprić, paprič, kišnec ili korion. Zeleni plodovi, listovi i drugi zeleni delovi biljke su neprijatnog mirisa na stenice (na grčkom *coris* – stenica, pa otuda i naziv biljke) (Jevtić et al., 1986), dok je seme karakterističnog i prijatnog mirisa. Seme korijandera može biti okruglog ili ovalnog oblika sa rebrastom semenjačom. Klija i niče na temperaturi od 6 do 7°C. Sveže seme ima visoku klijavost koja nakon 2–3 godine naglo opada (Pavlović et al., 2002). Seme sadrži 0,4–1,5% etarskog ulja, 18–28% masnih ulja i do 30% belančevina, pa se posle destilacije etarskog ulja iz semena ostaci koriste za ishranu stoke (Kišgeci i Adamović, 1994).

Etarsko ulje semena korijandera predstavlja smešu raznih derivata terpenoida, alkohola, aldehida, ketona i etara, i glavni je izvor za dobijanje linalola (60–80%), koji se upotrebljava u industriji parfema, kozmetici i industriji sapuna. U humanoj medicini, korijander ulazi u sastav različitih lekova za lečenje organa za varenje. Korijander se koristi i u veterinarskoj medicini, a i u industriji likera, piva, peciva i slatkiša, kao zamena za biber i cimet (Kišgeci i Adamović, 1994).

Brojni biotski i abiotski faktori mogu negativno uticati na zdravlje biljaka i kvalitet semena korijandera. Među biotskim faktorima značajno mesto zauzimaju fitopatogene gljive *Fusarium oxysporum* f. sp. *corianderi*, *Protomyces macrosporus*, *Erysiphe polygoni, Cercospora corianderi, Phoma multirostrata* i *Colletotrichum gloeosporioides* (Khare et al., 2017). Neke od patogenih gljiva kao što su *Pythium* spp*., Alternaria alternata, Fusarium* spp*., Macrophomina phaseolina, R. solani* i *Sclerotium rolfsii* mogu izazvati bolest semena ili se njime prenositi. Patogene gljive mogu biti prisutne na ili u semenu, na ili u semenjači, ekstraembrionalno ili intraembrionalno, a mogu biti i kontaminanti semena. Njihovo prenošenje semenom može izazvati pojavu lokalne ili sistemične zaraze biljaka. S ciljem zaštite semena i biljaka od patogena koji se prenose semenom ili izazivaju bolesti semena, važno je znati lokaciju patogena u semenu. Takođe, značajno je i poznavanje vremena infekcije matične biljke kako bi se proizvelo seme koje nije zaraženo.

U Srbiji su detektovane četiri vrste iz roda *Alternaria* – identifikovane kao patogeni semena biljaka iz familije Apiaceae: *A. dauci*, *A. radicina*, *A. petroselini* i *A. alternata,* koje su prouzrokovale smanjeno nicanje semena mrkve, peršuna, paškanata i celera. *A. dauci*, *A. radicina* i *A. petroselini* pokazali su se kao agresivniji patogeni u odnosu na *A. alternata* (Bulajić et al., 2009). Prema navodima Coles i Wicks (2003), izolacijom patogena iz zaražene biljke dokazano je da *A. radicina* napada mrkvu u svim fazama razvoja izazivajući isušivanje i trulež korena, krune, peteljke i listova. Takođe, utvrđeno je i da je *A. alternata* patogen semena mrkve. Dokazano je da *A. dauci* izaziva lisnu pegavost i sušenje lista, a *A. radicina* crnu trulež na korenu, listu i semenu mrkve (Bulajić i Krstić, 2007).

Patogeni koji se prenose semenom izazivaju razvoj i širenje bolesti i gubitak prinosa, menjaju hemijski sastav i biološke osobine semena, pre svega klijavost, i utiču na biljku koja nastaje njegovim klijanjem. S ciljem zaštite semena od bolesti, mogu se koristiti mehaničke, fizičke, hemijske i biološke mere. Poslednjih nekoliko decenija, upotreba konvencionalnih pesticida u suzbijanju štetnih agenasa u poljoprivredi bila je standardna praksa. Njihova učestala primena na direktan ili indirektan način šteti okolini, zdravlju ljudi i životinja. Iz ovog razloga, nameće se potreba za pronalaženjem i uvođenjem manje opasnih i otrovnih supstanci u zaštiti biljaka (Klokočar-Šmit et al., 2006). Zahvaljujući novim pravcima, potreba za proučavanjem i primenom etarskih ulja i biljnih ekstrakata u zaštiti gajenog bilja od bolesti se povećava i sve više dobija na značaju. Njihova primena u zaštiti semena gajenih biljaka, može uticati kako na klijanje, tako i na smanjenje zaraze semena patogenima (Karaca et al., 2017). U istraživanjima Montes-Belmont i Carvajal (1998), etarsko ulje pitome nane bilo je testirano u zaštiti semena kukuruza od patogene gljive *Aspergillus flavus*, dok su Karaca et al. (2017) etarsko ulje pitome nane koristili za tretiranje semena pšenice protiv patogenih vrsta iz rodova *Tilletia*, *Alternaria* i *Aspergillus*. Efikasnost etarskog ulja pitome nane ispitivana je i u suzbijanju patogena semena paradajza i rotkvice (Mahdavikia i Saharkhiz, 2015).

U istraživanjima Hussain et al. (2010) etarska ulja biljaka iz roda *Mentha* ispoljila su antifungalno delovanje prema vrstama roda *Alternaria* i potencijal da se pored ishrane mogu koristiti i u zaštiti bilja i semena od fitopatogena. Zbog toga je cilj ovog rada bio da se nakon utvrđivanja zdravstvenog stanja semena korijandera, ispita i mogućnost njegove dezinfekcije primenom etarskog ulja pitome nane poznatog hemijskog sastava.

Materijal i metode

Poreklo i ispitivanje zdravstvenog stanja semena korijandera

U istraživanjima je korišćeno seme korijandera dobijeno iz Instituta za proučavanje lekovitog bilja „Dr Josif Pančić", proizvedeno 2016. godine. Zdravstveno stanje semena korijandera ispitivano je standardnom laboratorijskom metodom na filter papiru. Na prethodno sterilisan (110ºC, 1h) i navlažen filter papir postavljeno je nesterilisano seme korijandera. Semena su inkubirana sedam dana u vlažnoj komori, pri temperarturi od 22±2ºC. Postavljeno je ukupno 500 semena korijandera (pet ponavljanja po 100). S ciljem poređenja, 100 semena su prethodno sterilisana u 1% rastvoru NaOCl, u trajanju od pet minuta i inkubirana na isti način. Nakon sedam dana inkubacije, obavljen je makroskopski i mikroskopski pregled semena i izvršena je izolacija gljive na hranljivu podlogu od krompir dekstroznog agra (PDA) (Potato dextrose agar, EMD, Germany).

Izolacija i identifikacija patogena

Izolacija patogena obavljena je iz zaraženih semena i klica nakon sedam dana inkubacije prethodno netretiranog semena na filter papiru u uslovima sobne temperature. Za izolaciju patogena, semena i klice sa simptomima nekroze, sa ili bez prisustva micelije ili spora gljiva, preneti su na PDA hranljivu podlogu. Semena i klice su pre nanošenja na hranljivu podlogu prethodno sterilisana u 70% rastvoru etil alkohola, u trajanju od 1 minuta. Petri kutije su oblepljene parafilmom i inkubirane na sobnoj temperaturi. Nakon sedam dana razvijene kulture gljive su presejane na sterilnu PDA podlogu s ciljem dobijanja čiste kulture. Kod dobijenih izolata identifikacija patogena obavljena je na osnovu makroskopskih (boja i izgled kolonije) i mikroskopskih morfoloških odlika (izgled konidija). Za posmatranje mikroskopskih odlika gljiva koje su se razvile na semenu i u kulturi korišćen je mikroskop Carl Zeiss Axio Lab.A1 (Zeiss, New York, United States), a fotografije su snimljene kamerom Axiocam ErC.5s (Zeiss, Göttingen, Germany).

Poreklo i analiza sastava etarskog ulja pitome nane

U ispitivanju je korišćeno etarsko ulje nadzemnog dela pitome nane (*Mentha* x *piperita*), poreklom iz Srbije, proizvedeno i nabavljeno na slobodnom tržištu od Herba d.o.o., Beograd. Kvalitativna i kvantitativna analiza uzorka etarskog ulja vršena je primenom gasne hromatografije i dva tipa detektora. Klasične analitičke gasnohromatografske analize urađene su na Agilent Technologies gasnom hromatografu, model 7890A (Agilent, Santa Clara, USA), opremljenom *split-splitless* injektorom povezanim sa HP-5 kolonama (30 m x 0,32 mm, debljine filma 0,25 μm) i plameno-jonizujućim detektorom (FID). Kao noseći gas korišćen je vodonik (1 ml/min/210°C). Temperatura injektora iznosila je 250°C, detektora 280°C, dok je temperatura kolone menjana u linearnom režimu temperaturskog programiranja od 40 do 260°C (4°/min). Isti analitički uslovi korišćeni su i za potrebe GC/MS analize rađene na HP G 1800C Series II GCD analitičkom sistemu, s tim što je tu rađeno sa HP-5MS kolonom (30 m x 0,25 mm x 0,25 μm) i što je kao noseći gas korišćen helijum. Temperatura transfer linije iznosila je 260°C. Maseni spektri snimani su u EI režimu (70 eV), u opsegu m/z 40–400.

U svim slučajevima rastvori uzorka etarskog ulja (1 μl) u etanolu injektirani su u *split*-režimu (1:30). Identifikacija pojedinačnih komponenata vršena je maseno spektrometrijski i preko Kovačevih indeksa, uz korišćenje različitih baza masenih spektara (NIST/Wiley), različitih načina pretrage (PBM/NIST/AMDIS) i raspoloživih literaturnih podataka (Adams, 2007). Za kvantifikacione svrhe kao osnova uzeti su procenti površina pikova dobijeni integracijom sa odgovarajućih hromatograma (GC/FID).

Ispitivanje uticaja etarskog ulja pitome nane na zarazu semena korijandera

Seme korijandera (100 semena po tretmanu) potapano je u rastvore etarskog ulja pitome nane različitih koncentracija (1, 2, 5 i 10%), u kojima je držano u vremenskom trajanju od 1 minuta. Ulje je rastvarano u vodi sa dodatkom 1% Tween 20 (Sigma-Aldrich, Germany). Nakon potapanja semena u rastvor, posuda je povremeno mućkana kako bi se rastvor ulja ravnomerno rasporedio na sve delove semena. Potom je seme korijandera osušeno na filter papiru i postavljeno u Petri kutije, na vlažan filter papir i inkubirano na sobnoj temperaturi u trajanju od sedam dana. U ispitivanjima uticaja tretmana korišćene su tri kontrole: K1 – 1% Tween 20 (s ciljem utvrđivanja delovanja emulgatora na prisutne patogene na semenu), K2 – 1% rastvor NaOCl (s ciljem površinske dezinfekcije semena), i K3 – bez tretmana. Kontrolna semena su inkubirana na isti način kao i tretirana semena. Posle sedam dana posmatrana je pojava zaraze semena i određen je broj zaraženih semena. Procenat inhibicije zaraze semena pod uticajem različitih koncentracija etarskih ulja izračunat je po formuli: % inhibicije = [(K–T) / K] x 100, gde su: K – broj zaraženih semena u kontroli (K1 ili K3) i T – broj zaraženih semena u tretmanu.

Statistička obrada podataka obavljena je metodom analize varijanse. Značajnost razlika između srednjih vrednosti određena je uz pomoć Student-Newman-Keuls testa višestrukih intervala za nivo značajnosti $P \leq 0{,}05$. Statistička analiza obavljena je korišćenjem programa IBM SPSS Statistics 25.

Rezultati i diskusija

Zdravstveno stanje semena korijandera i identifikacija patogena

Nakon sedam dana inkubacije u vlažnoj komori na sobnoj temperaturi, na zaraženim semenima pojavili su se uniformni simptomi i znakovi prisustva patogena. Uočena je pojava simptoma nekroze na semenu i klicama, kao i prisustvo tamne micelije i obilne sporulacije maslinastosive boje (slika 1). Nivo zaraze semena iznosio je od 30% do 42%, u proseku 35,2% (zaraza i kontaminacija semena patogenom), dok je procenat zaraze kod semena tretiranog 1% rastvorom NaOCl iznosio 19% (endogena zaraza patogenom).

Nakon izolacije dobijeni izolati na PDA podlozi formirali su obilnu, vunastu i tamnu maslinastosivu koloniju. Mikroskopskim pregledom uočeno je da su izolati formirali višećelijske, feodiktiosporne konidije u nizovima (slika 2), maslinastosmeđe boje, elipsoidnog ili ovalnog oblika sa kratkim koničnim kljunom, sa 2–7 poprečnih i 0–3 uzdužnih septi.

Slika 1. Zaraženo seme korijandera: simptomi nekroze na semenu i klicama i prisustvo tamne micelije i obilne sporulacije.
Figure 1. The infected coriander seed: symptoms of necrosis on seeds and germs and the presence of dark mycelia and abundant sporulation.

Slika 2. *Alternaria* sp.: konidije u nizovima.
Figure 2. Alternaria sp.: *conidia in chains.*

Na osnovu makroskopskih i mikroskopskih odlika, a poređenjem sa podacima iz literature (Thomma, 2003; Woudenberg et al., 2013; Lawrence et al., 2016), izolati gljiva poreklom sa semena korijandera identifikovani su kao *Alternaria* sp. sekcija *Alternaria.*

Hemijski sastav etarskog ulja

Na osnovu sadržaja glavnih komponenti, etarsko ulje pitome nane, korišćeno u našim istraživanjima, odgovaralo je sadržaju koji propisuje međunarodni standard koji definiše kvalitet ovog ulja (ISO856:2006). Ukupno je identifikovano 38 komponenti u ovom ulju, od kojih su najdominantnije bile mentol, menton, izo-menton, mentil acetat, (Z)-kariofilen i 1,8-cineol, zajedno čineći 80,7% ukupnog sastava ulja. Dominantnu hemijsku klasu ulja predstavljali su oksigenovani monoterpeni (tabela 1).

Tabela 1. Hemijski sastav etarskog ulja pitome nane (*Mentha* x *piperita*), familija *Lamiaceae.*
Table 1. The chemical composition of the essential oil of Mentha x *piperita, family Lamiaceae.*

Komponente/*Components*	RI	%	Komponente/*Components*	RI	%
α-pinen	927	0,1	pulegon	1241	1,3
β-pinen	969	0,2	piperiton	1269	0,5
α-terpinen	1013	0,1	*neo*-mentil acetat	1270	0,3
p-cimen	1019	0,5	mentil acetat	1291	6,6
limonen	1023	2,7	*izo*-mentil acetat	1303	0,3
1,8-cineol	1025	4,5	dihidrodrokarvil acetat	1308	0,1
γ-terpinen	1053	0,4	*β*-elemen	1386	2,5
cis-sabinen hidrat	1064	0,2	(*Z*)-kariofilen	1408	4,4
α-terpinolen	1086	0,1	*β*-kopaen	1431	0,1
linalol	1097	0,2	aromadendren	1435	0,2
amil izovalerat	1103	0,2	*α*-humulen	1446	0,3
izo-pulegol	1141	0,1	germakren D	1480	0,6
menton	1151	23,5	biciklogermakren	1498	1,8
izo-menton	1160	6,6	*δ*-kadinen	1516	0,5
mentol	1173	35,1	*trans*-nerolidol	1545	0,2
terpinen-4-ol	1176	1,6	spatulenol	1572	0,7
izo-mentol	1179	0,3	kariofilen oksid	1574	1,0
α-terpineol	1187	0,4	globulol	1583	0,8
mentil-formijat	1232	0,1	*α*-kadinol	1647	0,3
			Monoterpene hydrocarbons		*4,0*
			Oxygenated monoterpenes		*81,9*
			Sesquiterpene hydrocarbons		*10,4*
			Oxygenated sesquiterpenes		*2,9*
			Total identified (%)		*99,2*
			Number of identified components		*38*

Smanjenje zaraze semena može se postići različitim merama zaštite, od mehaničkih, fizičkih, hemijskih do bioloških. Poslednjih nekoliko decenija, zbog posledica učestale primene pesticida, nametnula se potreba za pronalaženjem i uvođenjem u upotrebu manje opasnih i otrovnih supstanci u zaštiti bilja (Klokočar-Šmit et al., 2006). S tim u vezi, primena preparata na bazi biljaka, uključujući i produkte njihovog sekundarnog metabolizma, posebno etarska ulja, sve više dobija na značaju (Marković, 2011). Etarska ulja su aromatična i lako isparljiva, kompleksna prirodna jedinjenja za koje postoje podaci da utiču na inhibiciju zaraze semena gajenih biljaka u manjoj ili većoj meri (Karaca et al., 2017), što je potvrđeno i u ovom istraživanju.

S obzirom na to da se seme koristi u proizvodnji korijandera i u ishrani ljudi i životinja, važno je naglasiti da etarsko ulje *M. piperita*, kojim je seme korijandera tretirano u našem istraživanju, poseduje GRAS status, kao i da se njegove glavne komponente mogu smatrati bezbednim u ishrani (U.S. Food and Drug Administration, 2008). Osim toga, ovo ulje ispoljava i širok spektar antifungalne aktivnosti (Schuhmacher et al., 2003; Matan et al., 2009).

Uticaj etarskog ulja pitome nane na zarazu semena korijandera

Etarsko ulje pitome nane primenjeno u koncentracijama 1, 2, 5 i 10% ispoljilo je negativan uticaj na pojavu *Alternaria* sp. na semenu korijandera (tabela 2). Najveća inhibicija uočena je tretiranjem semena korijandera etarskim uljem koncentracija 5 i 10% (inhibicija 69,33%). Uočeno je i da 1% rastvori Tween 20 (K1) i NaOCl (K2) ispoljavaju negativno delovanje (inhibicija 25,33% i 38,67%), kao i da se njihovo delovanje na pojavu *Alternaria* sp. nije statistički značajno razlikovalo od delovanja etarskog ulja u koncentraciji 1% (inhibicija 30,67%). Kada se delovanje etarskog ulja posmatra u odnosu na delovanje 1% rastvora Tween 20 (K1) uočava se da i etarsko ulje pitome nane u koncentraciji 2% ispoljava antifungalno dejstvo, tj. statistički značajno veću inhibiciju patogena od emulgatora (tabela 2).

U sprovedenim istraživanjima, uočeno je variranje u procentu zaraze ispitivanih semena koje je iznosilo od 30% do 42% kod partije semena korišćene za ispitivanje zdravstvenog stanja, u odnosu na 64% do 84% kod partije semena korišćene za ispitivanje delovanja etarskih ulja. Ovo govori o različitom prisustvu patogena iz roda *Alternaria* kod različitih partija semena i u saglasnosti je sa rezultatima Bulajić et al. (2009) da seme začinskog bilja iz familije Apiaceae ispoljava različit stepen zaraze fitopatogenim gljivama roda *Alternaria*. Zaraza semena *Alternaria* spp. je kod ovih biljnih vrsta veoma značajna, jer dovodi do smanjenja prinosa. Zbog toga je osnovni preduslov za dobar prinos zdrava biljka koja se razvija iz zdravog semena (Bulajić i Krstić, 2007; Bulajić et al., 2009).

Tabela 2. Uticaj etarskog ulja pitome nane na pojavu gljive *Alternaria* sp. na semenu korijandera.
Table 2. The effect of the essential oil of Mentha x piperita on the occurrence of the fungus Alternaria sp. on the coriander seed.

Tretman semena *Seed treatment*	Broj zaraženih semena (prosek ± SD) *Number of infected seeds (average ± SD)*	Inhibicija u odnosu na K3 *Inhibition calculated against K3* (%)	Inhibicija u odnosu na K1 *Inhibition calculated against K1* (%)
Etarsko ulje *Essential oil*			
1%	52 ± 7,3 b*	30,67 b	11,91 b
2%	36 ± 8,6 ab	52 ab	35,71 a
5%	23 ± 6,8 a	69,33 a	58,93 a
10%	23 ± 3,8 a	69,33 a	58,93 a
Kontrola *Control*			
K1 – 1% Tween 20	56 ± 16,7 b	25,33 b	/
K2 – 1% NaOCl	46 ± 18,6 b	38,67 b	/
K3 – netretirano *nontreated*	75 ± 8,9 c	/	/

*Srednje vrednosti označene istim slovom ne razlikuju se značajno prema Student-Newman-Keuls testu (P≤0,05).
**Mean values followed by the same letter are not significantly different according to the Student-Newman-Keuls test (P≤0.05).*

Prema rezultatima koje su naveli Moghaddam et al. (2013), 5% Tween rastvor etarskog ulja *M. piperita* poreklom iz Irana (menton 30,6%, mentol 25,16%, mentofuran 6,47%) ispoljio je aktivnost na fitopatogene gljive *Fusarium oxysporum* f. sp. *ciceris*, *Dreschlera spicifera* i *Macrophomina phaseolina*, mada su mnogo pre istraživači Carta et al. (1996) sugerisali da i druge komponente ulja *M. piperita* pospešuju njegovu sveukupnu antifungalnu aktivnost. U istraživanju koje su sproveli Souza et al. (2014), etarsko ulje *M. piperita* poreklom iz Brazila i njegova glavna komponenta mentol ispoljili su različitu *in vitro* inhibitornu aktivnost na porast micelije *F. oxysporum*, pri čemu je izolovana komponenta mentol ispoljila znatno bolju aktivnost (mentol 100%, a ulje 55% inhibicije). Prema Soković et al. (2009), antifungalna aktivnost 1% Tween rastvora ulja *M. piperita* (mentol 37,4%, mentil acetat 17,4% i menton 12,7%) i ulja *Mentha spicata* (karvon 69,5% i menton 21,9%), ispoljili su različit stepen inhibicije na fitopatogene gljive iz roda *Aspergillus* (*A. niger, A. ochraceous, A. versicolor, A. flavus*) i *Penicillium* (*P. ochrochloron, P. funiculosum*). Prema Freire et al. (2011), 0,1% Tween 20 rastvor ulja *M. piperita* (mentol 54,2%, menton 7,3%, neomenton 6,3%), ispoljio je različitu antifungalnu aktivnost na niz postžetvenih patogena (*A. flavus*, *A. glaucus*, *A. niger*, *A. ochraceous*, *Colletotrichum gloeosporioides*, *C.*

musae, F. oxysporum i F. semitectum). Dobru antifungalnu aktivnost na postžetvene patogene prijavili su i Hadian et al. (2008), sa primenom 5% Tween 80 rastvora iranskog ulja *M. piperita* (mentol 36,2%, menton 32,4%) na *Rhizopus stolonifer* i *A. niger*, kao i Edris i Farrag (2003) sa uljem *M. piperita* poreklom iz Amerike (mentol 36,2%, menton 32,4%, izomenton 7,58%), na *Sclerotinia sclerotiorum*, *R. stolonifer* i *Mucor* sp. U poslednjem istraživanju zajedničko delovanje mentona i mentola ispoljilo je snažniju antifungalnu aktivnost od samog ulja. Prema Moghtader (2013), DMSO rastvor etarskog ulja *M. piperita*, takođe poreklom iz Irana (mentol 38,33%, menton 21,45% i mentil acetat 12,49%), ispoljio je jaču antifungalnu aktivnost na *A. niger* u poređenju sa antibiotikom (gentamicin), a autor smatra da je za pomenutu aktivnost bio odgovoran mentol. U istraživanju koje su sproveli Sellamuthu et al. (2013), ulje *M. piperita* (menton 46,45%, mentol 21,69%) poreklom iz južne Afrike, ispoljilo je antifungalnu aktivnost na *C. gloeosporioides.*

U istraživanju Soković et al. (2009), 1% Tween rastvor etarskog ulja *M. piperita* (mentol 37,4%, mentil acetat 17,4% i menton 12,7%), testiran je u *in vitro* uslovima i na patogenu gljivu *A. alternata* i ispoljio je fungicidno delovanje (MFC 1,0–2,5 μL/mL), dok je u istraživanju França et al. (2018) čisto etarsko ulje *M. piperita* neprikazanog hemijskog sastava, dodato u PDA podlogu (0,4% i 0,8%), ispoljilo inhibitornu aktivnost na porast micelije *A. alternata* (13,27% i 72,45%). Prema Perveen i Bokahri (2020), 0,5% Tween 20 rastvor ulja *M. arvensis* (mentol 69,2%), dodat u PDA podlogu u koncentraciji od 40 μL/mL, ispoljio je potpunu inhibiciju porasta micelije i klijanja konidija *A. alternata*, dok je u istraživanju Plavšić et al. (2020), 0,1% Tween 80 rastvor etarskog ulja *M. piperita* iz Srbije (mentol 39,9%, menton 23,51%, mentil acetat 7,29%), ispoljio fungicidno delovanje na više fitopatogenih gljiva, uključujući *A. alternata* (MFC 1,7–454,5 μl/mL). Prema Reddy et al. (2019), disk impregniran 10% DMSO rastvorom ulja *M. piperita* iz Saudijske Arabije (mentol 36,02%, menton 24,56%, mentil acetat 8,95%), postavljen na hranljivu podlogu, na koju je zasejana *A. alternata*, rezultirao je inhibicijom porasta (MIC 1,50 μg/mL).

Sadržaj glavnih komponenti u *M. piperita* ulju testiranom u ovom radu, u poređenju sa ranije opisanim delovanjem na patogenu gljivu *A. alternata*, bio je različit; mentol je uvek bio nešto niži (35,1%), menton je bio druga najzastupljenija komponenta ulja i bio je često viši (23,5%), dok je sadržaj mentil acetata bio dosta niži (6,6%). Kako u većini istraživanja autori uglavnom sugerišu da su glavne komponente najčešće zaslužne za uspeh antifungalne aktivnosti ulja *M. piperita,* proizilazi da je za postizanje antifungalne aktivnosti nekog ulja njegov hemijski sastav suštinski važan. To je u saglasnosti i sa rezultatima Soković et al. (2009), gde se među nekoliko testiranih izolovanih glavnih komponenti ulja *M. piperita*, mentol izdvojio snažnom antifungalnom aktivnošću ne samo na *A. alternata* već i na ostale ispitivane fitopatogene gljive. Od uticaja etarskih ulja na druge fitopatogene vrste roda *Alternaria* nije bilo istraživanja sa uljima izolovanim iz biljaka roda *Mentha* L. U istraživanju Parveen i Sharma (2018), efikasnost na *A. solani* ispoljila su ulja *Ocimum bascillicum, O. sanctum, O. tenuiflorum*, *O. citriodorum*, *Cymbopogon citrates* i *Origanum majorana*, pri čemu su samo prva dva ulja ispoljila potpunu inhibiciju porasta micelije. Rezultati dobijeni u ovom ispitivanju, kao i literaturni podaci, pokazuju da etarsko ulje biljaka roda *Mentha* poseduje dobar antifungalni potencijal prema *Alternaria* spp. Uvođenje etarskih ulja, kao jedne od mera dezinfekcije semena korijandera, može smanjiti pojavu bolesti prouzrokovanih fitopatogenim gljivama roda *Alternaria* i time unaprediti proizvodnju korijandera.

Zaključak

Zaraženo seme je jedan od glavnih izvora inokuluma biljnih bolesti za narednu sezonu. Zbog toga je ispitivanje zdravstvenog stanja semena, utvrđivanje prisustva patogena semena i mogućnost njegove dezinfekcije, poželjno preparatima na prirodnoj osnovi, važno kako bi se za zasnivanje useva korijandera obezbedilo zdravo seme.

Ispitivanjem zdravstvenog stanja semena korijandera proizvedenog u Pančevu 2016. godine, mikroskopskim pregledom i izolacijom gljiva na PDA hranljivu podlogu, utvrđeno je prisustvo patogena iz roda *Alternaria* sekcija *Alternaria*. Simptomi su bili u vidu nekroze semena i klica. Jedan odabrani izolat formirao je obilnu, vunastu, maslinastosivu koloniju i višećelijske, feodiktiosporne konidije u nizovima, maslinastosmeđe boje.

Rezultati ovih ispitivanja jasno ukazuju na značaj dezinfekcije semena korijandera u smanjivanju zaraze *Alternaria* sp. Najefikasnije dejstvo ispoljilo je etarsko ulje pitome nane (2, 5 i 10%), ali je smanjivanje zaraze ostvareno i potapanjem semena korijandera u 1% rastvore Tween 20 i NaOCl. Etarsko ulje *Mentha* x *piperita*, poreklom iz Srbije, po sadržaju glavnih komponenti odgovaralo je ISO standardu koji propisuje njegov kvalitet, mada su ovi sadržaji bili na donjim granicama. Ulje, primenjeno u koncentracijama 5 i 10% (rastvoreno u 1% Tween 20), radi kratkotrajne dezinfekcije semena korijandera, ispoljilo je inhibitornu efikasnost 69,33%, odnosno 58,93% kada se izuzme delovanje Tween 20. Prema tome, povećavanje koncentracije primene etarskog ulja je, nakon prvobitnog trenda rasta, dostiglo najviši nivo efikasnosti pri koncentraciji etarskog ulja od 5%. Za postizanje bolje inhibitorne aktivnosti, verovatno bi bilo korisnije primeniti ulje čiji bi sadržaji glavnih komponenti bili viši od ispitivanog, odnosno bliži gornjim granicama ISO propisa koji definiše kvalitet ovog ulja. Takođe, korisno bi bilo uraditi preciznu identifikaciju patogena roda *Alternaria* prisutnih na semenu korijandera, s obzirom na pretpostavku da se javljaju u kompleksnim zarazama od više vrsta koje se mogu razlikovati po svojoj osetljivosti prema primenjenom etarskom ulju.

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THE POSSIBILITY OF CORIANDER SEED DISINFECTION WITH THE ESSENTIAL OIL OF PEPPERMINT

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A b s t r a c t

Seed health testing aims to ensure a healthy crop and to prevent the spread of plant diseases. The need to study and apply both essential oils and plant extracts against seed diseases is growing and becoming more important. Coriander (*Coriandrum sativum* L.) is an annual herbaceous, aromatic, spicy and medicinal plant from the Apiaceae family, known for its seeds with a characteristic and pleasant odour. In human medicine, coriander is a part of various medicines for the treatment of digestive organs. Phytopathogenic fungi and bacteria are the most common and significant causes of coriander seed disease. The aim of this study was to assess coriander seed health and investigate the possibility of seed disinfection using peppermint (*Mentha* x *piperita*) essential oil. The health of the seeds was examined by the filter paper laboratory standard method. Different concentrations (1, 2, 5 and 10%) of peppermint essential oil were used for seed disinfection. The composition of the essential oil was determined by gas chromatographic analysis. The results of seed health analysis showed the presence of a fungus after seven days of incubation in a humid chamber at room temperature. The fungus was identified as *Alternaria* sp. (sect. *Alternaria*) based on the symptoms and macroscopic and microscopic features of the fungus (on seed and potato dextrose agar). Immersion treatment of infected seed in peppermint essential oil reduced the presence of *Alternaria* sp. on coriander seeds. The highest disease inhibition, 69,33%, namely 58,93% without the influence of the emulsifier, was shown by oil solution of 5%. Stagnation in inhibition was observed with a further increase in oil concentration. The results of this study show the possibility of disinfecting coriander seeds with peppermint essential oil to reduce infection with *Alternaria* sp.

Key words: seed health, coriander seed, peppermint (*Mentha* x *piperita*) essential oil, *Alternaria* sp.

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THE EFFECT OF AGE, BIRTH WEIGHT AND MILK SUCTION TIME ON SOME CARCASS CHARACTERISTICS AND LOAD DISTRIBUTION RATIO (LDR): EASTERN ANATOLIAN RED CATTLE EXAMPLE IN TURKEY

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Abstract: The aim of this research is to evaluate the current situation and create a model for some countries involved in animal production. Eastern Anatolian Red (EAR) breed that adapts to arid and barren areas has been raised in Turkey. The experimental animals comprised 31 head of EAR cows of different ages, fed on pastures and in the barn. This study determined the effects of age, birth weight and suction time on carcass characteristics of EAR cows. The animals were divided into 6 groups based on birth weight, 4 groups based on age and 6 groups based on milk suction time. They were reared under a conventional system that was based on grazing during summer and a semi-intensive system during winter. Carcass length, fat thickness over longissimus dorsi, marbling score, and LDR were significantly ($P< 0.05$) affected by age group. Significant ($P< 0.05$) differences were noted for carcass length, fat thickness over LD, and marbling score among animals with different birth weights. The milk suction time had a significant ($P< 0.05$) effect on all the parameters measured. In this research, the 4th age group was seen advantageous based on carcass characteristics and LDR and resembled other groups. As indicated in the study, the carcass characteristic output from the 2nd birth weight group shows that carcass length was a far more important output than other carcass portions or carcass quality parameters. Similarly, the 1st group based on milk suction time came to the forefront for some carcass characteristic, although it indicated partial similarity with other groups.

Key words: meat production, carcass characteristics, domestic cow, Eastern Anatolian Red, rearing style.

Introduction

The suitability and low cost of materials such as animals, feeds and labor to procure a profitable and sustainable yield from available sources can be of

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extensive potential contribution to livestock production enterprises. Most mixed production enterprises exploit the multipurpose use of domestic and mixed breeds for low risk, cost and labor (VanRaden and Sanders, 2003). The cows that are not intended to benefit from themselves except for milk and calf have been considered as materials that can be used directly in meat production or as the breeding material in meat production improvement in recent years (Scholtz and Theunissen, 2010). The existence of cows adapted to extensive conditions is a significant revenue source for farms practising mixed rearing as these animals are quickly sold due to the reasonable market prices. Indigenous cattle diversity is the most important resource of life conditions in rural Turkey. Even if there are the indigenous cattle breeds over the country, they are mostly concentrated in high settlements, steep lands, marginal areas, and low-quality pastures. Eastern Anatolian Red (EAR) breed in the eastern region mainly consists of widely medium-small body size, adapted to marginal areas, dark red color, horned, of harsh temperament, abstemious character (Yüksel et al., 2011) and deep-rooted past (Ozdemir and Dogru, 2009). There are considerable exploitable variation and normal fertility in reproductive performance in EAR cattle. Reproductive failure was often reported to be a significant cost (Arnot et al., 2015). Özlütürk et al. (2004) have stated that the EAR cattle also show superior characteristics (e.g. fertility and ease of birth) compared to some exotic cattle. Despite the smaller body size, they have shown phenotypic progress as for the disease and pests (Yüksel et al., 2011). The relationship between birth weight and calf loss was studied by Özlütürk et al. (2007), who stated that it could be high until being the one-year-old in the enterprise. Another issue that needs attention, similarly to the relationship between birth weight and living performance, is productiveness, based on the relationship between living resistance and intake milk amount. An issue that needs attention is based on the relationship between birth weight, milk suction time, cow age and carcass characteristics. The decision about this unique issue is quoted, not to diminish the general importance of intensive rearing and exotic cows in most developing regions, but simply to highlight the need to closely examine how and why farmers use their indigenous animals while deciding on the rearing method or production objectives in any given situation.

The overall objective of this research was to identify the most appropriate evaluation possibilities for indigenous EAR cows. As this breed differs with from other breeds, characteristics may respond differently to environmental factors. The potential use of the EAR breed in meat production was identified under certain rearing conditions in eastern Turkey. The goal was to determine the effect of cow age, birth weight and milk suction time for carcass characteristics and LDR. Thus, creating a model between breeders and EAR breeding, will improve public opinion and environmental sensitivity.

Material and Methods

The experimental animal materials comprised 31 head of EAR cows of different ages, produced by the Eastern Anatolian Agricultural Research Institute (EAARI). These animals were reared in two individual facilities at the EAARI. The calves born in the enterprise were fed milk, hay, and concentrate for six months. Starting from the 6th month of age, all animals were fed in a semi-intensive production system until being one-year-old. Then, animals were fed on meadow hay, alfalfa hay, wheat straw, concentrate (Table 1) in closed barns from November to April, and by grazing (Table 1) in pastures from May to October.

Table 1. The chemical composition of feeds (DM basis).

Feeds	DM %	CP %	EE %	Ash%	ADF %	NDF %
			Winter period			
Alfalfa hay	90.66	19.61	2.13	9.53	31.06	41.10
Meadow hay	92.26	10.13	2.10	8.90	39.55	62.40
Wheat straw	91.23	3.53	1.48	8.43	50.10	67.75
Concentrate	88.25	12.45	3.1	7.00	-	-
			Summer period			
PM	23.6	19.06	3.96	11.13	24.20	37.40

DM: dry matter; CP: crude protein; ME: metabolizable energy; CA: crude ash; ADF: acid detergent fiber NDF: neutral detergent fiber, EE: ether extract, PM: pasture mix (Agropyron cristatum, Trifolium repens, Dactylis glomerata).

According to the traditional rearing model, the animals were fed ad libitum in the winter period and by grazing in summer. The cows were transported over a distance of 4 km to the slaughterhouse, where they were kept in the paddock with free access to water. After four hours of resting, animals were slaughtered by industrial standards. Hot carcass weight was determined, and carcasses were divided into half-carcasses by cutting according to the standard criteria guided by the USDA (1989). The load distribution ratio (LDR) among groups or the general herd was determined according to the load rate of each individual in the group. For this process, our model was used by evaluating the relevant parameters, as follows.

$$LDR = \left(\frac{Xi}{\Sigma\, X1+X2 \ldots Xn}\right) x\ 100 \quad (1)$$

Xi: i. individual, n: number of the herd

Twenty-four hours post-slaughter, in between two ribs (12th and 13th), measurements were made from right half-sections. Fat thickness over LD, LD area and the marbling score were measured on the longissimus dorsi (LD) muscle (USDA, 1989). The scale used for the marbling evaluation ranged from 1 to 6 (1 =

slight, 2 = small, 3 = modest, 4 = moderate, 5 = slightly abundant, 6 = abundant). Carcass length, round length, and width of the round were measured on the right half-carcass.

Data were processed statistically using SPSS 20.0 version IBM (SPSS, 2015). Within the first category, animals were divided into four groups based on their age: 30–60 month (m) = 1, 61–90 m =2, 91–120 m = 3, and 121–150 m = 4. Within the second category, animals were divided into six groups based on their birth weight: 12–13 kg = 1, 14–15 kg = 2, 16–17 kg = 3, 18–19 kg = 4, 20 –21 kg = 5 and 22–23 kg = 6. As for the third category, animals were divided into six groups based on their milk suction time: 50–60 days (d) = 1, 61–70 d = 2, 71–80 d = 3, 81–90 d = 4, 91–100 d = 5 and 101–110 d = 6. The effects of all categories on carcass length, round length, the width of the round, fat thickness over LD, LD area, marbling score, and LDR were determined by the least-squares method, using the formula:

$$Yijkl = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + e_{ijkl} \quad (2)$$

where Y_{ijkl} is the value of the analyzed parameter, μ is the population mean, A_i = the effect of i cow age groups, B_j = the effect of j birth weight groups, C_k = the effect of k milk suction time, $(AB)_{ij}$, $(AC)_{ik}$, and $(BC)_{jk}$ is the interaction and e_{ijkl} is a random error. Differences between means were estimated by the Tukey's test.

Results and discussion

The indicators belonging to some carcass characteristics of EAR cows as affected by different age groups in this study are presented in Table 2. Carcass lengths, comparing all groups, the 3rd and 4th age group scales were characterized better (Table 2). Significant ($P < 0.01$) differences were noted for the older age group. In all groups, the 4th group with 121–150 m (158.7 cm) had the highest carcass length measure – above the general average (151.5 cm). The interaction values among the age, the birth weight and the milk suction time groups were found not significant ($P > 0.05$) statistically. The width of the round and the round length of the age groups are reported in Table 2. Neither width of the round nor round length was affected ($P > 0.05$) by age group differences. Within the current study, the 4th group had a higher round length value (over grand mean) than others, irrespective of statistical evaluation. Similar results were observed in the width of the round.

Fat thickness over LD determined for different age groups varied between age groups. Fat thickness over LD was higher in the 2nd age group. Significant ($P < 0.05$) differences were observed for the highest fat thickness over LD (Table 2). In the 3rd and the 4th age groups, fat thickness over LD tended to display close resemblance, whereas in the 1st age group the lowest value was noted, well below the grand mean.

The area of LD, determined for different age groups, varied between cow age groups. Significant ($P > 0.05$) differences were not observed (Table 2) for the highest LD area value (47.1 cm^2, group 2).

In this research, significant good variation ($P < 0.05$) for the marbling score was found among the cow age groups. The 3rd and the 4th groups had the highest values (5.0 and 4.7 points, respectively).

Table 2. Means and standard errors for the carcass value in terms of age groups.

Dependent variable	Grand mean	Age group scales for cows (month)				Sig
		1	2	3	4	
CL (cm)	151.5±1.7	143.1^{b}±3.0	149.1^{ab}±3.74	155.0^{a}±4.1	158.7^{a}±2.7	**
RL (cm)	74.4±1.4	71.0±2.6	72.8±3.1	74.0±3.5	75.9±2.3	ns
WR (cm)	35.8±0.5	35.0±0.8	36.1±1.1	35.6±1.1	36.8±0.8	ns
FTLD (cm)	0.80±0.1	0.49^{c}±0.16	1.05^{a}±0.20	0.84^{b}±0.22	0.83^{b}±0.14	*
LDA (cm^2)	44.7±1.7	41.9±3.1	47.1±3.8	45.3±4.2	44.5±2.87	ns
MS	3.8±0.4	2.6^{c}±0.7	3.0^{b}±0.8	5.0^{a}±0.9	4.7^{a}±0.6	*
LDR (%)	3.2±0.1	2.7^{b}±0.2	3.2^{ab}±0.2	3.3^{ab}±0.2	3.6^{a}±0.2	*

1: cows aged 30–60 months; 2: cows aged 61–90 months; 3: cows aged 91–120 months; 4: cows aged 121–150 months; LD: longissimus dorsi; Sig: significant; **: $P < 0.01$; *: $P < 0.05$: ns: not significant; a–c: different letters represent values on the same line that are statistically different; CL: carcass length, RL: round length, WR: width of the round, FTLD: fat thickness over longissimus dorsi, LDA: longissimus dorsi area, MS: marbling score; LDR: load distribution ratio, load distribution rate among cow age groups in terms of hot carcass weight.

The effect of cow age groups on LDR is reported in Table 2. The grand mean in the present study amounted to 3.2%, and cow age groups ratios ranged between 2.7% and 3.6% ($P > 0.05$).

Based on birth weight and milk suction time (Tables 3 and 4), highly significant differences ($P<0.01$) were observed among the groups. The lowest carcass lengths were determined for birth weight groups and milk suction time groups, 143 cm, and 132 cm, respectively. The highest values for both groups were determined 157 cm and 156.5 cm, respectively. The differences in round length values among groups based on birth weight were not significant. A statistical difference at a level of importance $P < 0.05$ was found among values of the round length of EAR cows among groups according to milk suction time. The highest average round length (80 cm) was reached by the group with the milk suction time between 50 and 60 d (1st group). The lowest average round length (70.5) was found in the 2nd group with 61–70 d.

It showed an influence of the birth weight and the milk suction time of treatment cows on fat thickness over LD (Tables 3 and 4, respectively). In both sources of variation, differences in fat thickness over LD among groups were found statistically significant ($P < 0.05$). The highest representation according to birth weight was achieved by the 3rd group, the lowest value was observed in the 6th group. On the other hand, LD area among treatment groups for the milk suction time groups varied significantly ($P < 0.05$). The highest average LD area value (56.5 cm^2) was reached by the 5th group. On the contrary, the lowest average LD area was reached in the 2nd group. The grand mean in the milk suction time group for the LD area was 43.9 cm^2.

Marbling scores differed due to birth weight, and milk suction time (Table 3) and these changes were found to be significant ($P < 0.05$). The highest marbling score in terms of birth weight was reached by the 2nd and 4th groups (5 points each). On the other hand, the 1st and 5th groups had the highest marbling score value in the milk suction time, and the 2nd and 4th groups had the lowest value.

Table 3. Means and standard errors for the carcass value in terms of birth weight.

Dependent variable	Grand mean	Birth weight group scales for cows (kg)						Sig
		1	2	3	4	5	6	
CL (cm)	149.4±2.4	150.6^b±5.8	157.0^a±7.2	153.5^{ab}±3.0	148.7^b±5.0	143.5^c±7.2	143.0^c±5.8	**
RL (cm)	75.5±2.0	70.3±5.0	78.5±6.1	73.4±2.6	75.5±4.3	70.0±6.1	72.3±5.0	ns
WR (cm)	36.3±0.6	35.6±1.4	38.5±1.7	36.3±0.7	34.5±1.2	36.5±1.7	36.3±1.4	ns
FTLD (cm)	0.7±0.1	0.60^c±0.30	0.80^b±0.37	1.05^a±0.16	0.62^c±0.37	0.60^c±0.31	0.46^c±0.30	*
LDA (cm^2)	44.3±2.4	39.1±5.8	49.2±7.2	44.5±3.0	44.5±5.0	44.7±7.2	44.0±5.8	ns
MS	3.5±0.5	2.0^d±1.3	5.0^a±1.6	4.1^b±0.6	5.0^a±1.1	2.0^d±1.6	3.0^c±1.3	**

1: a birth weight of 12–13 kg; 2: a birth weight of 14–15 kg; 3: a birth weight of 16–17 kg; 4: a birth weight of 18–19 kg; 5: a birth weight of 20–21 kg; 6: a birth weight of 22–23 kg; Sig: significant; **: $P < 0.01$; *: $P < 0.05$: ns: not significant; a–d: different letters represent values on the same line that are statistically different, CL: carcass length, RL: round length, WR: width of the round, FTLD: fat thickness over longissimus dorsi, LDA: longissimus dorsi area, MS: marbling score.

Drennan et al. (2008) reported that correlations of carcass length with carcass meat proportion and carcass value were either not significant or low and negative. In accordance with this finding, the same researchers also reported the same result for live-animal length scores and carcass length. EAR cattle have not been considered to have a body length that would adversely affect meat production, contrary to the statements of Piedrafita et al. (2003). In our study, the interaction of the round length and the width of the round was not observed, most probably, due to breed characteristics and the diet style of treatment cows. Our results are not in agreement with those of Alberti et al. (2008), who found a significant variation between age and breed. On the other hand, Jenkins et al. (1981) have found that variations in the yield of carcass components are related to body size differences, unlike our findings.

Table 4. Means and standard errors for the carcass value in terms of milk suction time.

Dependent variable	Grand mean	Milk suction time group scale for cows						Sig
		1	2	3	4	5	6	
CL (cm)	148.6^{a}±1.8	156.5^{a}±5.3	132.5^{b}±5.3	153.2^{a}±3.7	146.3^{ab}±4.3	156.0^{a}±5.3	147.6^{a}±3.3	**
RL (cm)	74.1±1.7	80.0^{a}±4.9	70.5^{b}±4.9	72.5^{b}±3.4	76.0^{ab}±4.0	74.0^{b}±4.9	72.0^{b}±3.1	*
WR (cm)	35.8±0.6	36.5±1.8	38.0±1.8	36.7±1.3	35.6±1.5	33.0±1.8	35.4±1.1	ns
FTLD (cm)	0.8±0.1	1.6^{a}±0.2	0.7^{b}±0.2	0.9^{b}±0.2	0.4^{c}±0.2	0.8^{b}±0.2	0.6^{c}±0.1	**
LDA (cm^2)	43.9±2.3	49.7^{ab}±6.5	35.0^{b}±6.5	39.6^{ab}±4.6	42.3^{ab}±5.3	56.5^{a}±6.5	40.2^{ab}±4.1	*
MS	3.7±0.6	5.0^{a}±1.6	2.0^{c}±1.6	4.2^{b}±1.1	2.0^{c}±1.3	5.0^{a}±1.6	4.4^{b}±1.0	*

1: the drinking milk for 50–60 days; 2: drinking milk for 61–70 days; 3: drinking milk for 71–80 days; 4: drinking milk for 81–90 days; 5: drinking milk for 91–100 days; 6: drinking milk for 101 – 110 days; LD: longissimus dorsi; Sig: significant; **: P < 0.01; *: P < 0.05: ns: not significant; a–c: different letters represent values on the same line that are statistically different, CL: carcass length, RL: round length, WR: width of the round, FTLD: fat thickness over longissimus dorsi, LDA: longissimus dorsi area, MS: marbling score.

The fat thickness over LD of the EAR cows in this study was lower than the Serrana de Teruel breed in different physiological periods (Ripoll et al., 2016). A study reported back fat thickness for concentrate with roughage separately (CON) and total mixed ration (TMR) models in Hanwoo steers, 11.95 and 13.95 mm, respectively (Chung et al., 2017). The fat thickness over LD in the study was different from a study of Yüksel et al. (2009), who reported that fat thickness over LD did not differ among control, 4% SBP, 8% sugar beet pulp (SBP). On the other hand, the study was similar to Yüksel et al. (2019), who indicated that the fat thickness over LD differed among treatment groups. Although some researchers (Piedrafita et al., 2003) report that local and hard animals are not suitable for meat production because they make more fat, different results have been obtained in this research. The fat thickness over LD, which is an important indicator of the animal degree of fattening (Drennan et al., 2008), has come close to world standards (Anonymous 1) in this research.

Longissimus dorsi muscle is a high-value section of the beef carcass associated with lean meat content (Nogalski et al., 2013). It is always desirable that the area of this muscle is wide. Yüksel et al. (2019) reported significant differences among treatment groups in the LD area belonging to EAR bulls. However, Yüksel et al. (2012) failed to find a difference between groups including eighteen-month-old EAR bulls considering different feeding styles. The studies of Hanwoo Steers at different yield grades revealed no significant effect of live BW at slaughter on carcass leanness and fatness (Jung et al., 2013). However, according to some studies, the findings in this study were found to be low (Yüksel et al., 2009; Shin et al., 2011).

The marbling score is the strongest sign in many countries (Hocquette et al., 2005), and is also the major factor in the USA quality grade for beef quality attributes (Indurain et al., 2009). In the research carried out by Pacheco et al. (2011), when comparing 2.5-year-old Charolais steers and cull cows, the degree of the marbling score was similar to the 1st age group in our study. Thus, they could be classified as light. Young bulls of lower ages and different styles (Yüksel et al., 2012; Yüksel et al., 2009; Ünlü et al., 2008) had lower values of the marbling score than our results when compared with older cows.

It was observed that the 4th group had the highest load distribution (LDR). Some authors conclude that local animals will not be used for the production of meat (Piedrafita et al., 2003). However, this research indicated the opposite result of this claim. This type of a rearing model has increased profitability in regions with large bumpy areas not suitable for the market place, integrating plants and the intensive system. Animal buying-selling process in such areas requires the live and herd form, not individual. Thus, the weeding of smaller and poor condition animals in the herd will be prevented. Therefore, the high general performance of the herd has great importance in terms of trade. The share of individuals in the total carcass weight of the herd shows the carried load and is of great importance in increasing the general performance of the herd.

The conclusive statistical difference at a level of importance was not found among values of the width of the round among groups according to birth weight and milk suction time. There are some studies specifically intended for some farm animals (Sladek and Mikule, 2017; Mioc et al., 2011). Unfortunately, there is less information on the long-term consequences of carcass measurements related to birth weight for cattle. For this reason, this research is expected to be an infrastructure for researches to be conducted. Greenwood et al. (2006) reported that hot standard carcasses were 30 kg (7.6%) lighter in low compared with high birth weight cattle. Khattak et al. (2018), Koçyiğit et al. (2015) and Kisac et al. (2011) reported that there was linearity between the milk absorption time and the weight gain. Enriquez et al. (2011) stated concerning Reinhardt and Reinhardt (1981) that there was a great individual variation in describing natural weaning in domestic cattle.

Geenwood et al. (2006) stated that fat depth at the P8 (rump) site and dressing percentage did not differ due to birth weight; however, it was 0.4% of live weight greater among low than high birth weight cattle at an equivalent carcass weight. The fat thickness over LD, which is closely related to the different ration content and fattening style (Yüksel et al., 2012), is also related to the physiological period of the animal. This parameter, which is used in determining yield grade, is especially of great importance in carcass quality (Anonymous 1). The fat thickness over LD values of the subgroups (birth weight, milk suction time) within the main factors followed a generally stable course among the groups. In this study, it was observed that the fat thickness over LD values of the groups were close to world standards (Anonymous 1). The LD area values of the groups determined by birth weight showed differences among the groups. However, it was determined that these differences were not statistically significant.

Salient results of the milk suction time group correspond to the important LD area, i.e., cows with milk suction time between 91 and 100 d reached the highest LD area value (56.5 cm^2) in comparison with cows with other milk suction times. It has been observed that the LD area changes depending on some factors such as fattening time and age (Unlu et al. 2008), but it does not change regarding some factors such as ration content and fattening style (Yüksel et al., 2012; Yüksel et al., 2009). However, there is a need for new researches that will show the direct effect of milk absorption time.

It has been observed that the marbling score values of both birth weight and milk suction time exceeded the grand mean values. A marbling score is the most used element in determining meat quality (Troxel and Gadberry, 2009). Therefore, it is important to know the factors affecting this element in the short term or long term. Greenwood et al. (2006) reported that marble scores did not differ due to birth weight or pre-weaning growth, but differed due to genotypes and ages. It was reported that despite fat content differences, no marbling differences were observed by Guzek et al. (2013). The statistical difference at a level of importance $P < 0.05$ was found in terms of values of the marbling score among different treatment groups according to feeding styles (Yüksel et al., 2012).

Conclusion

Effective production planning entails a comprehensive considering of human need for profitable rearing, a thorough analysis of the feed, animal and labor potential of methods, and an assessment of social life impact (long- and short-term) that may influence local and regional conditions. In many different subzones found in the livestock regions, the sustainable development of EAR breeding may supply many advantages; labor to the essential users of livestock, to local and regional development authorities, government policy makers, and to consumer of meat. The 4^{th} group of cow age groups has several advantageous consequences, both the carcass characteristics and the LDR ratio. In addition, this group will also have the chance of giving at least one calf until the slaughter period. The 2^{nd} group needs to be taken into account as breeders develop policies based on birth weight in the EAR breed. Such policies will also affect the ratio of valuable muscles such as longissimus dorsi, depending on the BL advantage. Based on milk suction time, selection objectives must identify animals that perform well for carcass characteristics at different liquid feeding times and can cope with variation in the feeding program including lower milk. In ongoing and future breeding, greater emphasis needs to be focused on the utilization of the 3rd group for carcass characteristics and meat production, coupled with lower exploitation of produced milk. The necessity of creating active local rearing models in the world with EAR and similar breeds is felt significantly.

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UTICAJ STAROSTI, TELESNE MASE NA TELENJU I DUŽINE PERIODA SISANJA MLEKA NA NEKE ODLIKE TRUPA I PREKRIVENOSTI TRUPA LOJEM (PTL): PRIMER ISTOČNOANADOLSKOG CRVENOG GOVEČETA U TURSKOJ

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R e z i m e

Cilj ovog istraživanja je da se proceni trenutna situacija i da se napravi model za neke zemlje koje se bave stočarskom proizvodnjom. Istočnoanadolska crvena (IAC) rasa goveda koja je prilagođena sušnim i neplodnim područjima, uzgaja se u Turskoj. Eksperimentom je obuhvaćeno 31 grlo IAC krava različite starosti, koje su se hranile na pašnjacima i u štali. Ovom studijom su utvrđeni efekti starosti, telesne mase na rođenju i dužine perioda sisanja na karakteristike trupa IAC krava. Životinje su bile podeljene u 6 grupa na osnovu telesne mase na telenju, 4 grupe na osnovu starosti i 6 grupa na osnovu dužine sisanja mleka. Uzgajane su u okviru konvencionalnog sistema, koji se zasniva na ispaši tokom leta i u poluintenzivnom sistemu ishrane tokom zime. Dužina trupa, debljina masnog tkiva preko mišića *longissimus dorsi*, ocena mramoriranosti i PTL bili su značajno uslovljeni starosnom grupom ($P < 0,05$). Značajne ($P <0,05$) razlike zabeležene su u dužini trupa, debljini masnog tkiva preko mišića LD i oceni mramoriranosti kod životinja sa različitim telesnim masama na telenju. Dužina perioda sisanja mleka pokazala je značajan ($P < 0,05$) uticaj na sve izmerene parametre. U ovom istraživanju videlo se da je četvrta starosna grupa najpovoljnija na osnovu karakteristika trupa i PTL, u odnosu na druge grupe. Ispitivane karakteristike trupa su bile najpovoljnije u okviru druge grupe na osnovu telesne mase na telenju i pokazuje da je dužina trupa daleko važnija od ostalih delova trupa ili parametara kvaliteta trupa. Slično tome, prva grupa zasnovana na dužini perioda sisanja mleka najpovoljnije je uticala na ispitivane osobine kvaliteta trupa, iako je ukazivala na delimičnu sličnost sa drugim grupama.

Ključne reči: proizvodnja mesa, karakteristike trupa, goveda, istočnoanadolsko crveno goveče, sistem gajenja.

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THE INFLUENCE OF CUTTING THICKNESS, SHAPE AND MOISTURE CONTENT ON OIL ABSORPTION DURING POTATO FRYING

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Abstract: Potato chips and French fries are products which are often used in the human diet. The aim of this study was to investigate the influence of cutting thickness, shape and moisture content on palm olein uptake, as well as the quality of the palm olein during the production of fried potatoes. Blanching operation was conducted in water for 3 minutes at a temperature of 85°C, while the frying process was conducted in palm olein for 3 minutes at a temperature of 165°C. The peroxide value and free fatty acid content (% oleic acid) were determined by standard analytical methods. The oil content in samples was determined by the standard Soxhlet extraction (the reference method). The results showed that the potato chips had approximately four times more oil uptake compared to potato sticks. The oil content was significantly lower in blanched potato slices (by 43.3%) but significantly higher in blanched potato sticks (by 53.5%) compared to unblanched samples. The analyzed quality parameters of palm olein were within the allowable value range. Based on the results obtained in this study, it can be concluded that the thickness, surface area and moisture content of the potato had a significant effect on oil uptake.

Key words: fried potato, palm olein, surface area, peroxide value, free fatty acids content.

Introduction

The potato (*Solanum tuberosum*) is a tuberous vegetable that is the most commonly used in human nutrition. The reasons for its widespread use are that the potato has a favourable economic factor, and it is available throughout the year (Popović-Djordjević et al., 2018). In terms of nutrition value, this vegetable is a

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rich source of starch, amino acids, micro and macro elements, as well as numerous antioxidant compounds such as vitamins and polyphenols (Xu et al., 2009; Popović-Djordjević et al., 2020). There are several ways to prepare potatoes for a meal: cooking, stewing, baking and frying. However, frying is the most common method of processing potatoes in the human diet because it provides a tasty product with a crunchy texture. Before frying, potatoes can be cut into different thicknesses and shapes. Potato chips are usually cut into slices of 1–2 mm, while the French fries are cut into sticks 1 cm thick. The research has shown that slice thickness and total surface area of slices affected the absorbed oil content in the product (Gamble and Rice, 1988; Lioumbas and Karapantsios, 2012). The oil most commonly used for industrial frying is palm oil in combination with its liquid fraction, palm olein (Pande et al., 2012; Paunović et al., 2020). In relation to palm oil, palm olein has a higher oleic than palmitic acid content (Lin, 2011; Pande et al., 2012). Compared to other oils, palm oil has proven to be the most suitable due to its higher content of saturated fatty acids, as well as tocopherols, tocotrienols, carotenoids and chlorophyll, and therefore, it is oxidatively more stable (Edem, 2002; Pande et al., 2012; Mba et al., 2015). During the frying process, saturated fatty acids are more stable than unsaturated fatty acids and thus reduce the possibility of the formation of numerous compounds resulting from chemical reactions such as hydrolysis, oxidation, isomerization and polymerization (Choe and Min, 2007). From the aspect of health, this is very important because a significant amount of oil could be absorbed during frying potatoes (Moyano and Pedreschi, 2006). Increased oil uptake during the prolonged frying process is probably related to higher oil viscosity caused by polymerization reactions (Dana and Saguy, 2006). Therefore, the fried potatoes contain higher oil content and thus the fatty acid degradation products, which certainly affect the sensory properties and the health of consumers. In addition, the moisture content significantly affects oil absorption (Gamble and Rice, 1988; Pedreschi et al., 2008). Blanching is a technological operation that is used before vegetable freezing. This procedure achieves the inactivation of enzymes that would contribute to degradation changes in the frozen product during the storage period. Also, blanching achieves the expulsion of gases from plant tissue, partial reduction of microorganisms, as well as shortening the frying period of time. However, blanching increases the moisture content, and the aim of this study was to determine to which extent this moisture content affected the oil absorption during frying. In addition, this study aimed to investigate the influence of potato cutting thickness and shape on the absorption of palm olein, which was a medium for heat transfer by convection, as well as the quality of absorbed oil after a certain frying time.

Material and Methods

The material for this experiment was purchased at a retail store in Belgrade, Serbia. Potatoes were produced in Serbia. Palm olein originated from Malaysia.

Sample preparation. Two kilograms of potatoes were cut into thin slices 2 mm thick (potato chips) and sticks 1 cm thick (French fries) using a manual potato slicer. Potatoes were blanched for 3 minutes at a temperature of 85°C (500 g of each sample) and then fried in an open deep fryer (2 L of palm olein was poured) at a temperature of 165°C for 3 minutes. The frying process was repeated for potato chips and French fries, which were not blanched, under the same conditions.

All post-frying and fresh oil samples were compared by standard analytical methods for determining peroxide value (PV) and free fatty acid content expressed as % oleic acid (FFA; % ol. acid). The oil content was determined by the Soxhlet extraction method in all post-frying potato samples. There were seven potato samples: fresh potato (A), blanched potato slices (B), blanched potato sticks (C), fried potato slices (D), fried potato sticks (E), fried blanched potato slices (F) and fried blanched potato sticks (G). Also, there were five oil samples: palm olein sample before frying (1), palm olein sample taken after the fried potato slices (2), fried potato sticks (3), fried blanched potato slices (4) and fried blanched potato sticks (5).

The total dry matter content (DM) was determined by the standard gravimetric method [AOAC, 2005].

The peroxide value (PV) [SRPS EN ISO 660:2015], expressed in mmol/kg, was determined by the reaction of oil (dissolved in acetic acid and isooctane) with a solution of potassium iodide. The liberated iodine was then titrated with a standard volumetric sodium thiosulfate solution.

The free fatty acid content (FFA) [SRPS EN ISO 660:2015; ISO 660:2009], expressed as a percentage of oleic acid (% ol. acid) in 100 g of sample, was determined by the titration of a solution of oil dissolved in ethanol:ether (1:1) with an ethanolic solution of potassium hydroxide.

The oil content [SRPS EN ISO 659:2011] was determined by the standard Soxhlet method of extraction (the reference method).

Statistical analysis was performed using statistical software STATISTICA 12. The results are shown as the arithmetic mean of three replicates ± standard deviation, and the differences between samples were determined by the Duncan test. Results were considered at the significance level $\alpha = 0.05$. A correlation analysis was carried out using the same program.

Results and discussion

The results obtained in this study are given in Tables 1 and 2.

The results of absorbed oil content indicated a significant difference between the samples. The amount of absorbed oil in fried potato depends on several factors. The surface area of the potato in contact with oil, moisture content and frying conditions (time and temperature) are among the most important ones (Razali and Badri, 1995). In this study, the sample with the highest absorbed oil content was potato chips (Table 1). Compared to potato sticks, potato slices (potato chips) had a larger surface area in contact with oil, resulting in the potato chips having approximately four times more oil uptake. During frying, large voids in the food were created due to water evaporation which was replaced by oil, which explains the high content of absorbed oil in the fried product (Dana and Saguy, 2006). Gamble and Rice (1988) and Lioumbas and Karapantsios (2012) described similar mechanisms during potato frying. All these mechanisms explained that the cutting thickness certainly had an effect on the oil uptake in food. If the food was thinly sliced, there was more intense water evaporation which was replaced by oil. The surface area also influenced the oil absorption of blanched potato samples (Table 1). The amount of absorbed oil in fried blanched potato slices was significantly higher in relation to fried blanched potato sticks for the stated reasons.

Table 1. The dry matter and absorbed oil content in potato samples.

Potato sample	DM (%)	Oil content (palm olein) (%)
A	20.69	-
B	18.65	-
C	17.45	-
D	86.66	$39.85^{a} \pm 1.06$
E	38.46	$8.95^{d} \pm 0.82$
F	88.01	$22.60^{b} \pm 1.30$
G	36.73	$13.74^{c} \pm 0.61$

Values are presented as means±SD (n=3); Different letters indicate a significant difference between the samples at the significance level α = 0.05.

On the other hand, moisture content also affected the amount of absorbed oil. Blanching increased the moisture content of the samples by approximately 2% (Table 1). The content of absorbed oil in fried blanched potato samples changed significantly in relation to unblanched samples fried under the same conditions. Namely, the content of absorbed oil in fried blanched potato slices decreased by 43.3% in relation to unblanched potato slices (Table 1). In the study conducted by Rimac-Brnčić et al. (2004), obtained results have shown that the different pre-frying treatments significantly decreased the oil absorption, even by over 50%. The best result was obtained using a 0.5% solution of calcium chloride in the blanching process. Unlike the results obtained in Rimac-Brnčić et al. (2004) and our study, Pedreschi and Moyano (2005) have published that the blanching of potato slices before frying significantly increased the absorbed oil content. These authors pointed out that only the increase in frying temperature had the effect of reducing oil uptake. In the study of Al-Khusaibi and Niranjan (2012), the results have shown that the combination of blanching with high-pressure pretreatment may be used to reduce frying time but not oil uptake. The absorbed oil content was significantly higher (by 53.5%) in blanched potato sticks compared to the unblanched sample (Table 1). These results were consistent with the findings of Pedreschi and Moyano (2005) and Al-Khusaibi and Niranjan (2012). According to Bingol et al. (2012), the oil uptake in French fries could be significantly reduced using infrared dry-blanched as a pretreatment technique instead of commonly blanching. Bunger et al. (2003) observed a significant decrease in oil uptake by soaking potato strips in 3% NaCl solution for 50 minutes prior to frying.

In this study, palm olein was analyzed before and after frying to determine peroxide value and free fatty acid content as its quality parameters. The results showed that the peroxide value and free fatty acid content of all oil samples taken after frying were significantly higher compared to initial values in palm olein before frying, as expected (Table 2). These parameters increased immediately in a very short period of frying time (Gunnepana and Nawaratne, 2015; Paunović et al., 2020). On the other hand, peroxide values and free fatty acid content in all oil samples taken after the frying process did not indicate a significant difference between samples (Table 2). This can be explained by the fact that the frying period was too short (3 minutes) for numerous chemical reactions. However, during the prolonged frying process, as well as multiple frying, the peroxide value and fatty acid content could be significantly increased (Ebba et al., 2012; Gunnepana and Nawaratne, 2015; Paunović et al., 2020). As the frying time is prolonged, chemical reactions of hydrolysis, oxidation, isomerization and polymerization become more intense, and these oils have an unpleasant taste and aroma, and additionally become unsafe to the consumer health (Ebba et al., 2012; Kaleem et al., 2015).

Table 2. The peroxide value and free fatty acid content in oil samples.

Oil sample	PV (mmol/kg)	FFA (% ol. acid)
1	$2.00^{b} \pm 0.20$	$0.56^{b} \pm 0.12$
2	$3.20^{a} \pm 0.20$	$0.85^{a} \pm 0.12$
3	$2.80^{a} \pm 0.20$	$0.85^{a} \pm 0.12$
4	$3.20^{a} \pm 0.20$	$0.56^{b} \pm 0.12$
5	$2.80^{a} \pm 0.20$	$0.85^{a} \pm 0.12$

Values are presented as means±SD (n=3); Different letters indicate a significant difference between the samples at the significance level $\alpha = 0.05$.

Based on the results, it can be concluded that the oil uptake undoubtedly depends on the thickness and surface area of the potato. If the surface area in contact with oil is larger, the oil absorption in the product will be increased. The moisture content also affected oil uptake. The oil content was significantly lower in blanched potato slices but significantly higher in blanched potato sticks compared to unblanched samples. Since the frying period was short, the analyzed quality parameters of palm oil were within the allowable value range.

Conclusion

Frying is the most common method of processing potatoes in the human diet, and products are potato chips and French fries. Based on the results obtained in this study, it can be concluded that the thickness and surface area of the potato had a significant effect on oil uptake. Compared to potato sticks, potato chips had a larger surface area in contact with oil, resulting in the potato chips having approximately four times more oil uptake. Moisture content also affected oil uptake. The oil content was significantly lower in blanched potato slices (by 43.3%) but significantly higher in blanched potato sticks (by 53.5%) compared to unblanched samples. Since the frying period was short, the analyzed quality parameters of palm oil were within the allowable value range.

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UTICAJ DEBLJINE LISTOVA, OBLIKA I SADRŽAJA VLAGE KROMPIRA NA APSORPCIJU ULJA TOKOM PRŽENJA

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R e z i m e

Čips i pomfrit su proizvodi koji se često koriste u ljudskoj ishrani. Cilj ovog rada bio je da se istraži uticaj debljine listova, oblika i sadržaja vlage na apsorpciju palmoleina, kao i kvalitet palmoleina tokom proizvodnje prženog krompira. Operacija blanširanja izvedena je kuvanjem u vodi u trajanju od 3 minuta na temperaturi od 85°C, dok je prženje u palmoleinu izvršeno u trajanju od 3 minuta na temperaturi od 165°C. Vrednosti peroksidnog broja i sadržaja slobodnih masnih kiselina (% oleinske kiseline) utvrđeni su standardnim analitičkim metodama. Sadržaj ulja u uzorcima određen je ekstrakcijom po Soxkhlet-u (referentna metoda). Rezultati su pokazali da je čips apsorbovao oko četiri puta višu količinu ulja u odnosu na pomfrit. Sadržaj ulja bio je značajno niži u listovima krompira koji su prethodno blanširani (za 43,3%), ali značajno viši u štapićima krompira koji su blanširani (za 53,5%), u poređenju sa neblanširanim uzorcima. Analizirani parametri kvaliteta palmoleina bili su u granicama dozvoljenih vrednosti. Na osnovu rezultata dobijenih u ovom istraživanju, može se zaključiti da su debljina listova, površina i sadržaj vlage krompira značajno uticali na apsorpciju ulja.

Ključne reči: prženi krompir, palmolein, površina, peroksidni broj, sadržaj slobodnih masnih kiselina.

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CROATIAN MEDIUM-TERM SOFT WHEAT MARKET OUTLOOK

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Abstract: With Croatia's accession to the European Union (EU), numerous changes have taken place within the key agricultural markets. This primarily relates to the introduction of Common Agricultural Policy measures and instruments, the convergence of domestic agri-food product prices, the opening of the domestic market and the producer's adjustment to the business conditions within the EU single market. Sophisticated tools such as partial equilibrium (PE) econometric models are commonly used in the impact assessments of the integration processes and for the development of medium-term market outlook simulations. The aim of this research is to develop a medium-term outlook of the soft wheat market in the Republic of Croatia up to 2030. As an appropriate tool, the AGMEMOD (PE) model was used to provide baseline simulations. The model results simulate future trends of main agrarian policy indicators (sown area, production, yield, import, export and average producer price) on the soft wheat market. The Croatian soft wheat market outlook assumes *ceteris paribus* market conditions with the existing agricultural policy structure until the end of the simulated period. The main findings of the simulated outlook indicate a slight growth trend of sown areas, continued growth of yield and production, along with soft wheat exports increase in Croatia by 2030 compared to 2018. Furthermore, the soft wheat degree of self-sufficiency in Croatia is expected to be 114% by the end of the simulated period.

Key words: soft wheat market, outlook, partial equilibrium, simulation, AGMEMOD.

Introduction

Agriculture is defined as a strategic branch of the economy in the Republic of Croatia by the Law on Agriculture (NN 118/18). A significant part of Croatian agricultural production is crop production, and the production of soft wheat as the most important bread-making cereal has great economic significance. Crop production made 59.1% of total gross agricultural production in Croatia, and grain production made 57.2% of total crop production in 2018, according to the Croatian Bureau of Statistics (CBS) data. In the structure of total grain production, soft

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wheat production ranks second after corn (61.6%) production with a share of 26.7%. These two crops account for approximately 80% (corn 51.2%, soft wheat 29.5%) of the total arable land under grains.

Since Croatia joined the EU in 2013, soft wheat production has been stable at an average level of 793.751 tons, while the areas sown to soft wheat in the same period averaged at 152.761 ha. Regarding sown areas, a significant oscillation is noticeable from 203.427 ha of sown areas in 2013 to 116.150 ha in 2017 with a declining trend of soft wheat area sown.

Soft wheat yields in Croatia have had a growth trend since EU accession, amounting to 5.2 t/ha on average in the period from 2013 to 2018. In the same period, the average soft wheat yields at the EU level were 5.8 t/ha (EU-15 Member States averaged at 6.7 t/ha; EU-13 Member States at 4.3 t/ha). Croatia, which belongs to the group of EU-13 Member States, has higher levels of average soft wheat yields than the average yield levels of the new Member States, but it is still closer to EU-13 average yield levels in relation to the average soft wheat yields in the old Member States (Zrakić Sušac et al., 2020).

Croatia is not self-sufficient in its own production of agri-food commodities, and the deficit in the foreign trade of agri-food products amounted to approximately 1 billion euros in 2018 (Grgić et al., 2019; Ministry of Agriculture, 2019). However, as far as grain production is concerned, the situation is different, and Croatia has sufficient levels of production of all main grains, while the degree of self-sufficiency of soft wheat production amounted to 114.17% in 2018.

Average soft wheat producer prices from Croatia's accession to the EU until 2018 were also stable, and since then, they have been below the levels of EU average soft wheat producer prices with a slight downward trend (Kranjac et al., 2020). In the mentioned period, the average soft wheat producer price in Croatia was 106.72 EUR/t.

The aim of this research is to apply the partial equilibrium (PE) econometric model, and to develop a soft wheat market outlook in the Republic of Croatia, including historical (2000–2018) and simulated development of the main agrarian policy indicators within the same market up to 2030. The main agrarian policy indicators related to production, yields, imports, exports and average producer price are the most important indicators while developing evidence and model-based market simulations and assessments (Matthews, 2018; Colen et al., 2016).

Furthermore, medium-term model simulations of key agricultural product markets are an established practice of the European Commission and the scientific community. Such simulations provide impact assessments of existing agricultural policy measures on key agricultural markets (EC, 2020; Kranjac et al., 2019; Salamon et al., 2019; Chantreuil et al., 2013; Erjavec et al., 2006).

Material and Methods

The method used for this research was the AGMEMOD (*Agriculture Member State Modelling*) model, which is an econometric, dynamic, multiproduct, multi-country partial equilibrium (PE) model. The main role of this model is to generate medium-term simulations of key agricultural market products, i.e. *outlooks* up to 2030 (Kranjac et al., 2020). The model has many characteristics as named above, and its dynamic feature realizes in a way that simulated variables are susceptible to exogenous changes (policy and macroeconomic variables). Another model feature is the *bottom-up* approach which is based on the AGMEMOD common country-level model template specifically developed to reflect the state and situation of agriculture in a particular country and then combined into a composite EU model (Donnellan et al., 2001; Chantreuil et al., 2012). Furthermore, the country-level model is composed of many commodity market sub-models. For example, the grain sub-model consists of the following commodities: soft and durum wheat, corn, barley, oats and rye.

Each commodity market is based on annual time-series data, in this case, Croatian soft wheat market historical balance sheet data. Data in the model range from 1995 up to 2018, and they are compiled from national statistical offices or sources and cover data on production, consumption, imports, exports, beginning stocks and ending stocks in the form of balance sheets (CBS, 2019; Ministry of Agriculture, 2019).

In order for the model to satisfy the partial equilibrium condition, it is necessary to establish agricultural market equilibrium for each individual key, which implies the following equality at a certain product price:

$$Production_t + Beginning\ stocks_t + Imports_t = Domestic\ use_t + Ending\ stocks_t + Exports_t$$

Within the commodity market sub-models, in this case, for soft wheat, supply and demand, international trade and prices are endogenously determined within the model (Chantreuil et al., 2012). Country-level models demonstrate changes in the behavior of producers and consumers, changes in exogenous data (macroeconomic variables, technical progress, policy instruments) and prices (Figure 1). From exogenous and endogenous data using sets of econometrically estimated equations, the model generates simulations of endogenous variables.

The general form of the econometric equation according to which the model derives the output variables is the regression equation. Therefore, the general equation of the model can be written as:

$$Y = \alpha + \varepsilon\beta_1 X_1 + \varepsilon\beta_2 X_2 + \varepsilon\beta_3 X_3 \ldots + \epsilon \quad (1)$$

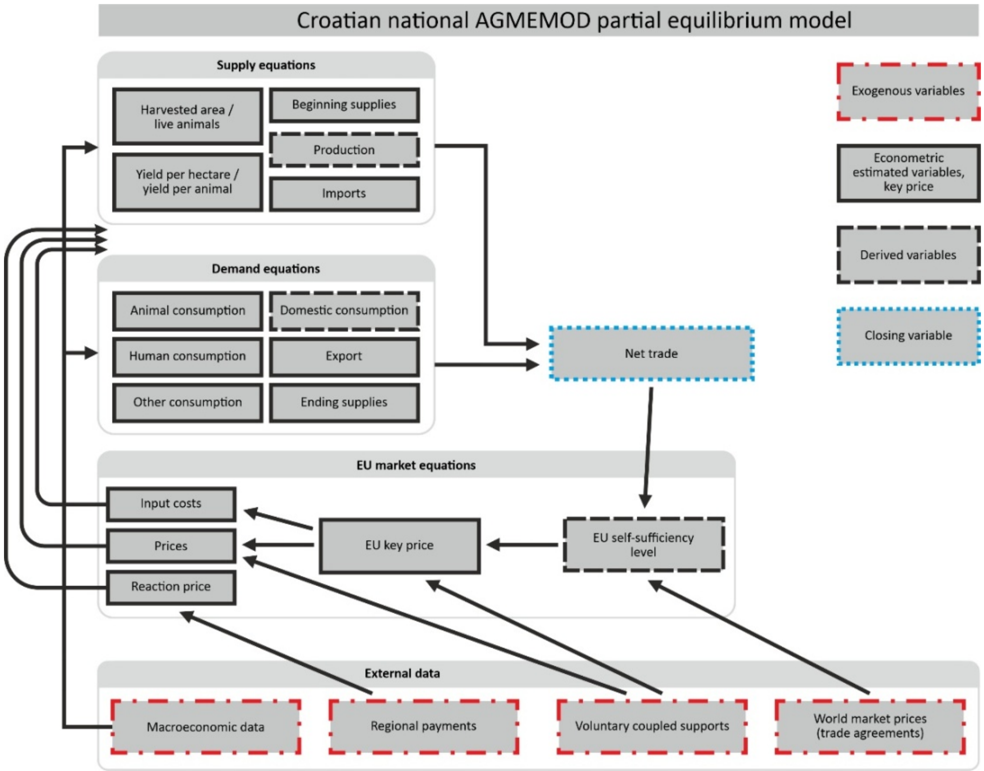

Figure 1. The Croatian AGMEMOD country-level model template.
Source: Authors' elaboration, according to Bartova and M'Barek (2008).

Equation 1 presents the standard regression equation, where *Y* is the dependent indicator, α is the intercept, ε – the elasticity coefficient, β – the regression coefficients, X_{123} are independent factors affecting the change of the dependent indicator, and ϵ is an error term.

Next, the general forms of econometric equations in the model used for the simulation of the soft wheat market in Croatia will be presented. Equation 2 presents the model equation for the total soft wheat area harvested, which can be written as:

$$ah_{i,t} = f\left(p_{i,t-1}^{j}, ah_{l,t-1}, V\right) \qquad j = 1,\ldots,n;\;\; i,l = 1,\ldots,3;\;\; i \neq l \qquad (2)$$

where *ah* presents the area harvested in year *t* for the culture group *i*, *p* is the real price in the year *t−1*of the culture *j* belonging to the culture group *i*, *prc* presents the change in price reaction in the year *t-1* of the culture *j* that belongs to the group culture and *V* is a vector, indicating an exogenous variable that can affect the harvested area.

Equation 3 presents the general equation used for soft wheat yield, and it can be written as:

$$r_{i,t}^{k} = f\,(p_{i,t-1}^{j}, r_{i,t-1}^{k}, V) \qquad\qquad j,k = 1,\ldots,n \tag{3}$$

$r_{i,t}^{k}$ is the yield of the culture *k* that belongs to the culture group *i* for the year *t*, *p* is the real price in the year *t−1*, and *V* presents a vector, indicating an exogenous variable that can affect the soft wheat yields (e.g. political instruments).

Based on the previous equations, the soft wheat production is determined: soft wheat production = soft wheat harvested area x soft wheat yield.

Equations 5 and 6 are general forms of import and export equations in the model, and they can be expressed as follows:

$$Ex_{i,t}^{k} = f\left(Pr_{i,t}^{k}, Du_{i,t}^{k}, Ex_{i,t-1}^{k}\right) \tag{4}$$

$$Im_{i,t}^{k} = f\left(Pr_{i,t}^{k}, Du_{i,t}^{k}, Im_{i,t-1}^{k}\right) \tag{5}$$

$Ex_{i,t}^{k}, Im_{i,t}^{k}$ are the export and import of the culture *k* in the culture group *i* for the year *t*, $PR^{k}i,t$ and $DU^{k}i,t$ present the production and domestic consumption of the culture *k* in the culture group *i* for the year *t*.

The equilibrium price of the individual agricultural product is modelled differently depending on whether the national product market is a key market with a key EU price or not. Croatian agricultural products do not have production levels that affect the European price, and agricultural production in Croatia amounts to only 0.62% of the value of EU agricultural production (Grgić et al., 2019). That is why Equation 6, which presents the equilibrium price on the Croatian market for all agricultural products, can be defined as:

$$p_{i,t} = f\left(Kp_{i,t}, p_{i,t-1}, ssr_{i,t}, Kssr_{i,t}, V\right) \qquad\qquad i = 1,\ldots,n \tag{6}$$

p is the Croatian price of the commodity *i* in the year *t*, *Kp* is the key price of the commodity *i* in the same year *t*, *ssr* presents the self-sufficiency ratio of the Croatian commodity *i* in the year *t*, *Kssr presents* the self-sufficiency ratio of the same commodity on the key EU market *i* in the year *t*, *V* presents a vector, indicating an exogenous variable that can affect the domestic soft wheat price.

Since AGMEMOD is a sectoral model, it integrates policy instruments well into the observed key agricultural market products. It does so through a policy harmonized approach (Salputra et al., 2011), including 2015–2020 CAP measures (SPS regional payments and coupled payments along with state aid payments for Croatia). These policy instruments are recalculated and included as policy price add-ons on the producer price for a specific commodity, in this case, soft wheat. Different levels of the reaction price affect production levels, harvested area, and so on. Rural development support measures are not included in the model because these types of models cannot include this type of supports.

The Croatian soft wheat market outlook is modelled using an appropriate econometric methodology as described by the general rules of the AGMEMOD modelling approach (Hanrahan, 2001; Erjavec and Donnellan, 2005). The outlook simulation assumes stable market conditions without market distortions with stable climatic and weather conditions (*ceteris paribus*) and with the continuation of existing agricultural policy measures up to 2030.

Results and Discussion

The quantities of soft wheat sown areas in Croatia have a declining trend. This trend is particularly pronounced after Croatia's accession to the EU (Figure 2). The soft wheat sown area declining trend is related to the relatively low soft wheat average producer prices in Croatia, which are below the levels of average producer prices in the EU (Iljkić et al., 2019). Therefore, a significant part of domestic soft wheat producers have reoriented their production to other field crops whose average producer prices are closer to the EU average producer price levels (Kranjac et al., 2020).

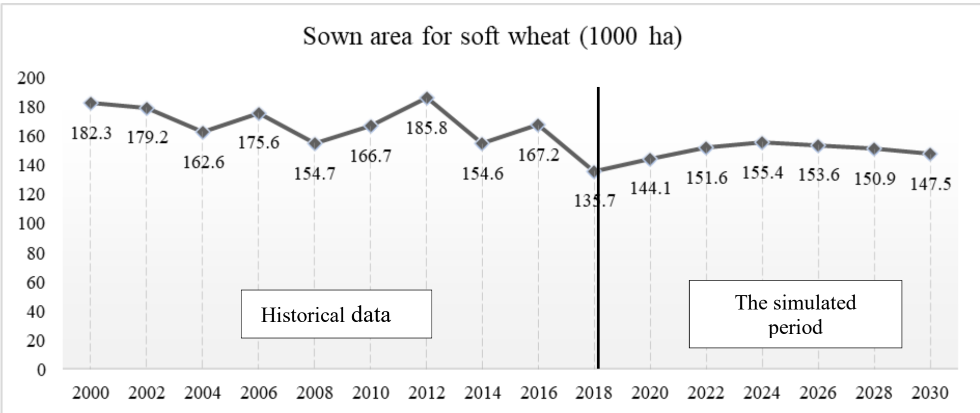

Figure 2. The medium-term outlook on the Croatian sown area for soft wheat by 2030.
Source: AGMEMOD v8.0 modelling results.

In the following period, according to the AGMEMOD model simulation results, the stable quantity of soft wheat sown areas with a slight growth trend until 2030 compared to 2018 is expected. The reason for this is the increase in demand for soft wheat for human and industrial consumption on the single market in the coming period with the stabilization and a slight increase in soft wheat prices.

Soft wheat yields in Croatia are stable as well and have a growth trend in the pre-accession and in the period after Croatia's accession to the EU (Figure 3). However, in general, the state of production technology related to arable farming in Croatia is still worse than in the old Member States, especially in terms of the average age and the working efficiency of agricultural machinery (Zrakić Sušac et al., 2020).

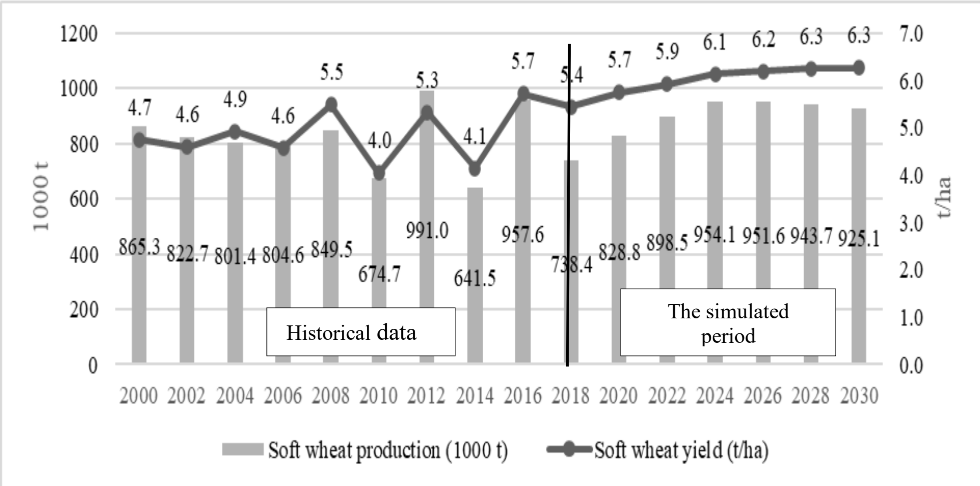

Figure 3. The medium-term outlook on Croatian soft wheat yields and production by 2030.
Source: AGMEMOD v8.0 modelling results.

The soft wheat market outlook simulation indicates that soft wheat yields in Croatia will continue to grow up to 2030. Respectively, further convergence of productivity per unit area is expected, where Croatia should approach the old Member States in terms of productivity levels. The introduction and development of new technologies in arable farming production, EU funding sources, Common Agricultural Policy (CAP) direct payments and mechanisms, changes in the landowner structure in favor of larger and more efficient farms should significantly contribute to such developments. Given the expected growth in yields and stable levels of sown areas, soft wheat production is also expected to grow by 25.28% by 2030 compared to 2018.

As we can observe from Figure 4, Croatia is self-sufficient regarding its own soft wheat production, and except in climate-unfavourable years, soft wheat exports are far higher than imports. Since Croatia's accession to the EU, the amount of exported soft wheat has increased as was the case in the other EU-13 Member States after their accession to the EU because direct payment measures effectively support intensive crop production (Csáki and Jámbor, 2009).

The model results indicate that soft wheat exports will increase slightly by 2030, with a slight decrease in imports compared to 2018.

By joining the EU, Croatia had to adjust domestic prices to EU prices, i.e. domestic agri-food product prices had to converge with prices on the single market. Given that domestic average producer soft wheat prices before joining the EU were approximately 15% higher than EU average soft wheat producer prices, it means that convergence of domestic prices caused additional pressure on domestic soft wheat producers (Kranjac et al., 2020). Since Croatia joined the EU, the average soft wheat producer price on the domestic market has remained below the levels of EU average soft wheat producer prices.

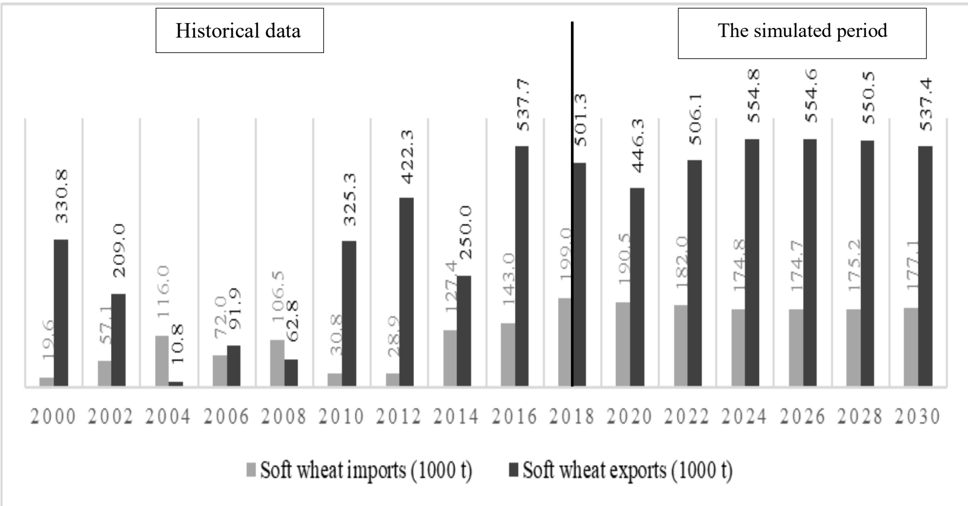

Figure 4. The medium-term outlook on Croatian soft wheat market imports and exports by 2030.
Source: AGMEMOD v8.0 modelling results.

In the following period, a slight increase in the average soft wheat producer price in Croatia is expected (Figure 5), and an increase of 19.78% by 2030 compared to 2018 has been simulated.

So far, the individual agrarian policy indicators analyzed through the model simulation within the soft wheat market in Croatia have had a positive trend, and its continuation is expected in the coming period. This primarily refers to a slight increase in soft wheat sown areas, continued growth in yields and soft wheat production in Croatia up to 2030. Given the positive aforementioned indicators, the degree of self-sufficiency on the soft wheat market in the Republic of Croatia is expected to be 114% by the end of the simulated period (Figure 6).

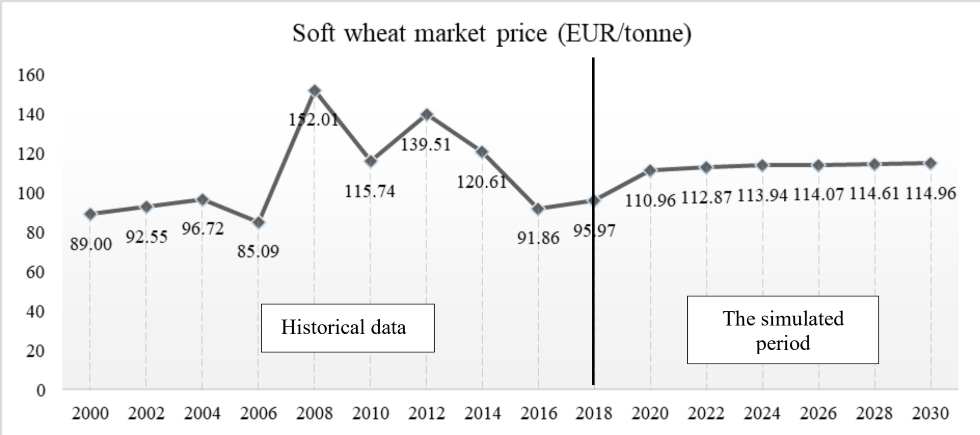

Figure 5. The medium-term outlook on the Croatian soft wheat average producer price by 2030.
Source: AGMEMOD v8.0 modelling results.

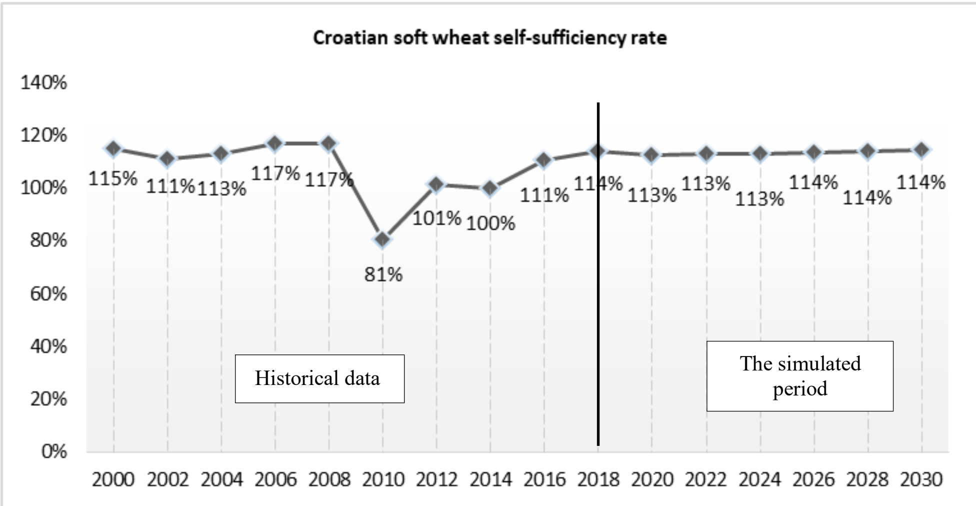

Figure 6. The simulated soft wheat self-sufficiency rate in Croatia by 2030.
Source: AGMEMOD v8.0 modelling results.

Conclusion

The AGMEMOD partial equilibrium model was used to simulate a medium-term outlook of the soft wheat market development in the Republic of Croatia up to 2030. The model results were simulated under *ceteris paribus* market conditions assuming the existing (2015–2020) structure of Common Agricultural Policy measures by the end of the simulated period. Simulated soft wheat market outlook results indicate an increase in soft wheat sown area, yields, production and net trade exports in Croatia by 2030. At the same time, domestic soft wheat average producer prices are expected to rise by the end of the simulated period, which will have a positive impact on the soft wheat growers. Furthermore, Croatia is expected to maintain a level of self-sufficiency on the soft wheat market, which is expected to be 114% by 2030.

Model outlook market simulations are not considered as forecasts but more as projections that correspond to the expected development of the individual agricultural market given the already existing average trends that are econometrically estimated and calibrated in the model. Also, partial equilibrium sector models of this type cannot include exogenous market shocks in their projected variables that are common in agricultural markets (sudden changes in market prices, unfavorable weather conditions, structural breaks, etc.). In addition, the model cannot assess the impacts of rural development measures and agri-environmental and climate policy instruments, which also play an important role in key agricultural market products. Therefore, further improvements are needed regarding the modelling approach that would include a stochastic modelling approach, rural development measures, agri-environmental and climate policy instruments in its simulated results.

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SREDNJOROČNI PREGLED TRŽIŠTA MEKE PŠENICE U REPUBLICI HRVATSKOJ

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Rezime

Pristupanjem Hrvatske Evropskoj uniji (EU) dogodile su se brojne značajne promene na ključnim poljoprivrednim tržištima. To se prvenstveno odnosi na otvaranje domaćeg tržišta i prilagođavanje proizvodnje i poslovanja unutar jedinstvenog EU tržišta, uvođenje mera i instrumenata Zajedničke poljoprivredne politike i konvergencija domaćih cena poljoprivredno-prehrambenih proizvoda. U procenama uticaja integracionih procesa, te za razvoj srednjoročnih simulacija tržišta poljoprivrednih proizvoda obično se koriste sofisticirani alati poput ekonometrijskih modela parcijalne ravnoteže (PR). Cilj ovog istraživanja je razviti srednjoročni pregled na tržištu meke pšenice u Republici Hrvatskoj do 2030. godine. U istraživanju je korišten AGMEMOD (PR) model pomoću kojeg je razvijana simulacija pregleda tržišta meke pšenice u Republici Hrvatskoj. Rezultati modela simuliraju buduće trendove glavnih agrarno-političkih pokazatelja (setvenu površinu, proizvodnju, prinos, uvoz, izvoz i prosečnu proizvođačku cenu) na tržištu meke pšenice. Pregled tržišta meke pšenice na hrvatskom tržištu pretpostavlja *ceteris paribus* tržišne uslove sa postojećom strukturom poljoprivredne politike do kraja simuliranog perioda. Glavni nalazi simuliranog pregleda ukazuju na blagi trend rasta zasejanih površina, nastavak rasta prinosa i proizvodnje, kao i porast izvoza meke pšenice u Hrvatskoj do 2030. godine u odnosu na 2018. godinu. Takođe, očekuje se da će stepen samodovoljnosti meke pšenice u Hrvatskoj iznositi 114% do kraja simuliranog perioda.

Ključne reči: tržište meke pšenice, pregled tržišta, parcijalna ravnoteža, simulacija, AGMEMOD.

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Original scientific paper

A COMPARATIVE ANALYSIS OF THE PROFITABILITY AND TECHNICAL EFFICIENCY OF VEGETABLE PRODUCTION UNDER TWO FARMING SYSTEMS IN NIGERIA

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Abstract: Increasing agricultural productivity enhanced by versatile production systems is critical for sustainable food security and economic development. The study aims to compare the profitability and technical efficiency of vegetable production and factors influencing the technical efficiency of vegetable production between inorganic and organic farming systems in Imo State, Nigeria. Primary data were collected using structured questionnaires comprising 100 vegetable farmers using a multistage sampling procedure. The budgetary analysis and stochastic production frontier model were used to estimate the profitability and the technical efficiencies of the enterprise. An average farmer realized ₦277,445.24 and ₦190,506.04 per hectare as profit from inorganic and organic vegetable production and can potentially earn ₦4.40 and ₦2.89 on every Naira invested, respectively. However, the inorganic farming system achieved significantly higher returns than the organic farming system. The mean technical efficiencies for organic and inorganic vegetable farmers were 89.57% and 75.64%, respectively. Farm size, labour and the quantity of seeds were the crucial factors that affected the technical efficiency under both farming systems. Also, age, years of education and farming experience were the significant variables that influenced the technical inefficiency of inorganic farmers, whereas years of education and household size significantly influenced the technical inefficiency of organic farmers. This study advocates for subsidized inputs for organic farmers to compensate for their lower yields and policies that would attract young people to vegetable farming to increase the production level.

Key words: comparative analysis, profitability, stochastic frontier, vegetable.

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Introduction

The introduction and usage of chemicals produced from fossil fuels into the farming system transformed and enhanced agricultural yield and productivity. Many were amazed by the intense transformation of the effects of these chemical aids on their farming activities and enterprises (Gandhl, 2014). Initially, soil contained various healthy compositions for great productivity (FAO, 2015); any damage brought about by chemicals such as fertilisers, pesticides, herbicides, fungicides and other synthetic compounds was hardly noticeable (Meena et al., 2020). It is a recognisable technology spread across the world as it was considered the revolution in agriculture (Pretty and Bharucha, 2015; Allongue, 2018). In recent times, the output and health benefits of organic farming have been marvelling (Seufert and Ramankutty, 2017; Chait, 2019). This came to existence due to the conventional knowledge about inorganic farming methods coupled with a host of problems, including health-related diseases like cancer, pollution, degradation of soil and water, and impact on domestic animals (Özkara et al., 2016).

In Africa, especially in developing countries such as Nigeria, organic farming is an ancient agronomic practice (Adebayo and Oladele, 2014). Organic farming can be explained as agricultural practices in natural ways. Over the years, it has been believed that the conventional or inorganic system of farming is more proficient in its output than the organic system (Panhwar et al., 2019). Yield differences may be due to a less productive technology or lower technical efficiency in production on organic farms, or both. Measured differences in productivity and efficiency may also be influenced by self-selection in the choice of production technology and thus not entirely attributable to organic standards. Efforts have been made to increase food productivity in Africa for the teeming population through innovative and sustainable farming systems (Osabohien et al., 2018). One of the alternative systems gaining prominence is organic farming. Today there exist widespread concerns that conventional agriculture is not sustainable in the long term (Tal, 2018). This is attributed mainly to the effect of artificial fertilisers and synthetic pesticides on the soil resulting in phenomena such as pesticide resistance and soil degradation; for example, erosion, acidity, salinity and compaction. The availability of information on the benefits and profitability of converting to organic farming could encourage farmers to produce vegetables organically (Röös et al., 2018). Therefore, knowing how profitable it is to produce vegetables organically is essential to reduce the amount of chemicals we consume and limit the havoc caused in our environment (Tuck et al., 2014).

In agricultural production, the efficiency with which the farmers put the farm inputs to use and the available technology are important (Mechri et al., 2017; Finger et al., 2019). The efficiency of any farm is measured for the following reasons; first, it is a success indicator and performance evaluator. Second, measuring the efficiency and separating its effects from the production environment determine the sources of the inefficiency. Third, it helps decision makers to monitor the performance of the unit under study (Bhatt and Bhatt, 2014). Also, identifying the most profitable technology is important. Profitability as the difference between the cost incurred and revenue generated should be checked in line with the technology used. Even though organic farming is better for a sustainable environment, profitability should also be compared with conventional practice (Alawode and Abegunde, 2015). The technology that is not profitable cannot survive in a market-oriented production, given the limited resources and the number of competing alternatives. The number of studies devoted to the question of how profitable organic agriculture is when compared to non-organic management is enormous; however, long-term studies analysing the development of profits in comparative studies are much less numerous (Specht et al., 2014). Regrettably, the geographical distribution of these studies is skewed towards developed countries and certain cash crops (e.g. soya bean, wheat, maize). However, a general trend can be identified when considering economic comparisons made in the last three decades (Kahan, 2013).

The idiosyncratic feature of this study is the methodology adopted and the study area, considering that the Imo State vegetable production has improved significantly over the last year. Therefore, the identification of the foundational issues concerning the sources of inefficiency is essential to the implementation of policies enacted to improve performance. This process would enable the formulation of policies about the factors targeted at raising the present efficiency level of vegetable farmers operating under inorganic and organic farming systems. A succinct understanding of these relationships is expected to provide the working tools for policymakers. In other words, it would encourage a designed program towards expanding vegetable production in Imo State in particular and in the nation at large. The necessity to compare the economic analysis of organic, inorganic and integrated technologies of vegetable production is hence the focus of this study. The specific objectives of this study are to:

i. estimate the yield of organic and inorganic vegetable farmers;
ii. compare the budgetary analysis of organic and inorganic vegetable production;
iii. estimate the technical efficiency of vegetable farmers under the inorganic and organic farming systems.

The hypothesis guiding this research work is:

Ho = There is no significant difference in the profitability of vegetables produced organically or inorganically;

Ha = There is a significant difference in the profitability of vegetables produced organically or inorganically.

Materials and Methods

Description of the study area

The study was conducted in Owerri, the capital of Imo State, Nigeria. Imo State is one of the five states of Southeast Nigeria. The Owerri municipal includes one community (Owerri Nchi Ise) and comprises five villages, including Amawom, Umuororonjo, Umuonyeche, Umuodu and Umuoyima. It is located between latitudes 5° 29′ north and longitudes 7°2′ east with a population of 1,401,873 and approximately 100km^2 in the area (NPC, 2006). Owerri is known for the tropical wet climate according to the Koppen-Geiger system. The rainy season begins in April and lasts until October (Climate and Weather, 2019), with annual rainfall varying from 1500 mm to 2200 mm (Kalu et al., 2014). The average annual temperature is above 20^{0}C, with an annual relative humidity of 75 per cent. The primary occupation in the study area is agriculture which comprises the cultivation of crops and rearing of animals. The predominant crops grown in Owerri, Imo State, are oil palm, rice, melon, cocoa, rubber, maize and vegetables. Consumable crops such as yam, cassava, cocoyam and maize are produced in large quantities.

Sampling techniques and sampling size

The population of this study comprises vegetable producing farmers in the Owerri municipal council area. A multistage sampling technique was used to select 100 vegetable farmers in the study area. The first stage was the purposive selection of the five villages in the Owerri municipal council area. The council area has the advantage that its communities and villages are proximal to the Federal University of Technology, Owerri. Hence, the council area communities are expected to benefit more relatively and directly from the university's extension and rural outreaches than communities in the other areas in the state. The second stage involved the simple random sampling of 20 vegetable farmers from the sampled five villages to make a total of 100 respondents. The data were then separated based on organic and inorganic farming for comparison.

Methods of data collection

Primary data were collected from the farmers through a questionnaire complemented by an interview. The interview was conducted in English, and in some cases, questions were interpreted in the respondent's local language for their better understanding. During the course of this study, several precautions were taken to ensure the protection of the rights of respondents to the questionnaire and interview. No questionnaire administration or interview began without the receipt of informed consent from each respondent. The data collected include socioeconomic characteristics of the vegetable farmers, the quantity and cost of various inputs employed in production, values of vegetables harvested and the yield of various vegetables cultivated.

Analytical techniques

Data were analysed using descriptive statistics (such as mean, tables and percentages), the t-test, the budgetary and stochastic production frontier model. Descriptive statistics were used to describe the socioeconomic characteristics of the farmers. The independent t-test was used to know the significant difference between the mean yield of the two groups, i.e. organic and inorganic farming. The budgetary techniques were employed in estimating the cost, returns, gross margin, net income (profit) and measures of profitability (such as profit per Naira invested) while the stochastic production frontier was used to analyse the technical efficiency of the vegetable enterprise in the study area.

The t-test estimation

In order to examine the differences in terms of variables that contribute to the calculation of vegetable yield among the farmers who practise organic farming and those practising inorganic farming, the t-test was conducted on various major costs. The rationale was to assess where the difference arises at the gross margin level. The vegetable yield was calculated by using the following formula:

$$Yield = \frac{Y}{A} \tag{1}$$

where (Y) represents the output, and (A) represents the area of land farmed.

The statistic t_{yield} (experimental t value) is then estimated thus:

$$t_{yield} = \frac{|\bar{x}_o - \bar{x}_i|}{S_{oi}\sqrt{\frac{1}{\cap_o} + \frac{1}{\cap_i}}} \tag{2}$$

t_{yield} value is compared with the critical value ($t_{critical}$) corresponding to the given degree of freedom N in the present case $N = \cap_o + \cap_i - 2$ and the confidence level chosen. The selection criteria are that if $t_{yield} > t_{critical}$ then H_0 is rejected, else H_a is retained.

Budgetary analysis

The mathematical specification of the budgetary techniques leading to the estimation of costs, returns, gross margin, net income (profit) and measures of profitability is as stated:

Profit (π) on vegetable enterprise = Gross Margin (GM) – Total Fixed Cost (TFC).

The computation of gross margin is given as:

$$\prod_j = [(P_y)Q_y]_j - \sum_{i=1}^{n}[(P_{xi}X_i) + TC]_j \quad (3)$$

where:

$\prod_j$ is the gross margin of the j^{th} farmer;

$[(P_y)Q_y]_j$ is the total revenue for the j^{th} farmer;

$[(P_{xj})X_{ij} + TC]_j$ is the total variable costs of the j^{th} farmer, which include the operational costs in the whole enterprise such as input costs, costs of labour (both skilled and unskilled) and transport costs.

T is the transaction costs.

P_y is the output price received by the j^{th}farmer.

Q_y is the output of the j^{th} farmer.

On the other hand, P_x is the input price paid by the j^{th} farmer for the i^{th} input or service and X_{ij} is the quantity of the i^{th} input or service used by the j^{th} farmer.

To use the gross margin as a measure of business performance, it is usually expressed in terms (as a ratio) of a major variable input. Consequently, higher gross margins for enterprise owners reflect greater efficiency or performance in turning the vegetables into income.

Fixed cost (TFC)

In other to estimate the fixed cost, the depreciated values of fixed items were estimated as follows:

$$\text{Fixed (depreciated) Cost (₦)} = \frac{PV-SV}{N} \quad (4)$$

where PV is the purchase value (₦), SV is the salvage value, N is the life span (in years).

The Total Fixed Cost (TFC) = $\sum_{d=1}^{H} P_{xd}X_{jd}$

where H is the number of fixed items with d indexing each fixed input.

Profitability

This is a measure of the performance of the vegetable enterprise. It was estimated using the returns to investment as stated in equation 5

$$\text{Returns to Investment (ROI)} = \frac{Total\ Revenue}{Total\ Cost} \quad (5)$$

RI is the amount of money that would be generated on a Naira invested in the business. The higher the rate of return, the more profitable an enterprise is during the period under consideration.

Technical efficiency of vegetable farmers

The stochastic production frontier (using the Cobb-Douglas functional form) was used to determine the technical efficiency or inefficiency of vegetable farmers in the study area. The stochastic production frontier model (Coelli, 1995) was adopted to specify the relationship between the input and output level of vegetable production in the study area. The production frontier model without a random component is written as:

$$yi = f(xi\ ; \beta).\ TEi \tag{6}$$

yi = the observed output of the ith vegetable farmer in kg;

xi = the vector of the input used by the ith vegetable farmer (farm size, labour, seed, manure/fertiliser, pesticide) and their relevant explanatory variables associated with the production of the ith vegetable farmer;

f(**xi;**β) = the production frontier (Battese and Tessema, 1992);

β = the vector of the unknown parameter associated with explanatory variables in the production function to be estimated;

TEi = the technical efficiency defined as the ratio of observed output to maximum feasible output.

A stochastic component that describes random shocks affecting the production process is added. These shocks are not directly attributable to the farmers or the underlying technology. The shock that may come from changes in weather or an economic adversity (v_i) denotes the shock effect and each farmer faces a different shock effect. The stochastic production frontier then becomes:

$$yi = f(x_i\ ; \beta).\ TEi\ .\ (v_i\ ) \tag{7}$$

TE_i is assumed to be the stochastic variable with a specific distribution common to all farmers. Thus, TE_i = $(-u_i\ )$ where $u_i \geq 0$. The function then becomes:

$$y_i = f(x_i\ ; \beta).\ exp(-u_i\ ).\ (v_i\ ) \tag{8}$$

Assuming that $(x_i\ ; \beta)$ takes the log-linear Cobb-Douglas form, the model is then written as:

$$lny_i = \beta_0 + \sum_n \beta_n lnx_{ni} + v_i - u_i \tag{9}$$

where:

yi = the output of vegetable harvested by the farmer (kg);

β_n = regression coefficients to be estimated;

x_i = input variables used in vegetable production;

v_i = the 'noise' component (i.e. stochastic disturbance term). $v_i's$ are assumed to be independently and identically distributed N (μ, σ_v^2) random errors (Battese and Tessema, 1992);

u_i = the non-negative technical inefficiency component. $u_i's$ are assumed to be independently and identically distributed non-negative truncations of μ and σ^2, (Battese and Tessema, 1992);

v_i *and* u_i together constitute a compound error term;

ln = the natural logarithm;

For inorganic farmers, equation 4 is expanded as:

$$lnY_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + e \tag{10}$$

where:
X_1 = land size (ha);
X_2 = labour (manday);
X_3 = seeds (kg);
X_4 = fertiliser (kg);
X_5 = pesticide (litre).
For organic farmers, equation 4 is expanded as:

$$lnY_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + e \quad (11)$$

where:
X_1 = land size (ha);
X_2 = labour (manday);
X_3 = seeds (kg);
X_4 = manure (kg);
e = the error term (assumed that it is truncated normal at zero N~(μu, σu^2).

Determining the factors affecting technical inefficiency for both groups (inorganic and organic), the following mathematical expression was used:

$$TE_i = \propto_0 + \propto_1 Z_1 + \propto_2 Z_2 + \propto_3 Z_3 + \propto_4 Z_4 + \propto_5 Z_5 + \propto_6 Z_6 + e_i \quad (12)$$

where:
Z_1 = age (in year);
Z_2 = gender (1 for female, 0 for male);
Z_3 = marital status (1 for married, 0 otherwise);
Z_4 = educational level (number of years of education);
Z_5 = household size (number);
Z_6 = years of farming experience (in year);
$\propto_1 - \propto_6$= parameters to be estimated;
TE_i = technical efficiency.

In this study, parameters of the stochastic frontier production function were estimated using the maximum likelihood estimation method using STATA version 12, which also estimated the variance parameter in terms of parameterisation:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad (13)$$

$$\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2) \quad (14)$$

$$\gamma = \sigma_u^2/(\sigma^2) \quad (15)$$

Gamma (γ), which is the variance ratio, has a value between zero and one ($0 < \gamma < 1$) (Battese and Tessema, 1992). The parameter γ is the total output attained at the frontier attributed to technical efficiency (Battese and Tessema, 1992), explaining the total variation in the output from the frontier level attributed to technical efficiency. Thus $1 - \gamma$ measures the technical inefficiency of vegetable farmers.

Results and Discussion

The average yield of organic and inorganic vegetable farmers

The distribution of the average yield of vegetable farmers across the farming systems is presented in Table 1. The average yields of vegetables were 6,287.19 kg/ha and 4,856.93 kg/ha under the inorganic and organic farming systems, respectively. The results showed that the average yield of vegetables under the inorganic farming system was significantly higher than the yield of vegetables under the organic farming system (p<0.01).

Table 1. The average yield of vegetables across farming systems.

	Inorganic vegetable production (kg/ha)	Organic vegetable production (kg/ha)	t-statistics
Average yield	6,287.19$^{\alpha}$	4,856.93$^{\alpha}$	4.412
Maximum yield	24,800	18,120	
Minimum yield	860	750	
Total yield	264, 061.96	281,701.71	

Source: Author's computation, 2018, $^{\alpha}$means that there is a significant difference.

Budgetary analysis of vegetable production under inorganic and organic farming systems

Budgetary analysis of vegetable production under organic and inorganic systems is presented in Table 2. The cost structure of vegetable production under inorganic and organic farming systems is explained. The labour cost accounted for about 36.2% and 80.3% of the total variable cost of production under the inorganic and organic farming systems, respectively. The average cost of organic manure was about ₦3,984.5, whereas inorganic fertiliser cost an average of ₦7,404.76. As reported earlier, organic farmers did not use pesticides on their vegetable farms, while the cost of pesticides for vegetable farmers under the inorganic farming system was ₦3,787.71. The cost of seeds was significantly higher under the inorganic farming system (₦3,952.38) than under the organic farming system (₦2,072.41 at the *p*<0.01 significance level). Transportation costs and costs of implements were significantly higher under the inorganic vegetable farming system at *p*<0.01 than under the organic vegetable farming system.

The total variable costs (TVCs) were significantly higher under the organic vegetable farming system than under the inorganic vegetable farming system and accounted for approximately 46.27% of the total cost incurred. The inorganic farming system achieved significantly higher total revenues generated from vegetables than the organic farming system (*p*<0.01). This is contrary to the findings of Alawode and Abegunde (2015), who found that the revenue from vegetable production under the organic farming system was significantly higher than under the inorganic farming system. Similarly, the net revenue was significantly higher under the inorganic farming system than under the organic farming system.

The results further revealed that the gross margins realised from both inorganic and organic farming systems were profitable, but the inorganic farming system had significantly higher returns than the organic farming system ($p<0.01$). The estimated returns on investment were (4.40) and (2.89) under the inorganic and organic farming systems, respectively. The result revealed that both systems were profitable, but the inorganic farming system had significantly higher returns on investment than the organic farming system ($p<0.01$). This indicated that an average farmer could realise about 4.40 Naira and 2.89 Naira on every Naira invested in vegetable production under the inorganic farming system and the organic farming system, respectively.

Table 2. The costs and returns of vegetable production under inorganic and organic farming systems.

	Inorganic vegetable production	Organic vegetable production	t-value
Costs (₦)			
Cost of labour	13,642.86$^{\alpha}$	51,913.79$^{\alpha}$	-3.687
Cost of organic manure	-	3,984.48	-
Cost of inorganic fertilisers	7404.76	-	-
Cost of pesticides	3,785.71	-	-
Cost of seeds	3,952.38$^{\alpha}$	2,072.41$^{\alpha}$	-4.156
Cost of transportation	3,280.95$^{\alpha}$	2,537.93$^{\alpha}$	-3.442
Cost of implements	5,661.90$^{\alpha}$	4,115.52$^{\alpha}$	-3.782
Total variable cost (TVC)	**37,728.57$^{\alpha}$**	**64,624.13$^{\alpha}$**	**-4.640**
Total fixed cost (TFC)	**43,809.52$^{\alpha}$**	**36,077.59**	**0.267**
Total cost (TC)	**81,538.09**	**100,701.72**	
Total revenue (TR)	358,983.33$^{\alpha}$	291, 207.76$^{\alpha}$	4.537
Net revenue	277,445.24$^{\alpha}$	190,506.04$^{\alpha}$	5.245
Gross margin	321,254.76$^{\alpha}$	226,583.63$^{\alpha}$	3.435
Return on investment	4.403	2.892	

Source: Field survey, 2018.

Estimates of the stochastic frontier production parameter under inorganic and organic farming systems

The maximum likelihood estimates (MLEs) of the Cobb-Douglas stochastic production model are presented in Table 3. The estimates of sigma-square (σ^2)

were 0.017 and 0.0357 for inorganic vegetable farming and organic vegetable farming, respectively. This indicates a good fit and correctness of the distribution assumption specified. The variance ratio gamma (γ), which measures the effect of technical efficiency in the variations of the observed output, had values of 0.8189 and 0.7893 for inorganic and organic vegetable farming systems, respectively. This implies that 81.89% (inorganic farming system) and 78.93% (organic farming system) of the difference between the observed and maximum production frontier outputs occurred due to differences in the producer's level of technical efficiency. The estimated chi-squares were large and significantly different from zero at 1%, indicating goodness of fit (best fit) and the correctness of the specified distribution assumptions for the decomposed error term.

Table 3 also reveals that, as for the inorganic farming system, farm size, labour, and the quantity of seeds are significant at the 1% level. All their coefficients are positive, implying that the 1% increase in these inputs (farm size, labour and the quantity of seeds) will lead to 1.028%, 0.096% and 0.001% increases in the quantity of vegetable production by the farmers, thus increasing the efficiency level, respectively. Also, for the organic farming system, farm size and the quantity of seeds are significant at the 1% level, and labour and the quantity of organic manure are significant at 5% and 1% levels. The coefficient of these significant variables (farm size, labour, the quantity of organic manure and the quantity of seeds) are positive, implying that the more these inputs are put into use in vegetable production, the higher the level of vegetables, thus increasing the technical efficiency and causing a decrease in the technical inefficiency.

The elasticities of the mean value of farm output with respect to farm size, labour, fertilisers and pesticides under the inorganic farming system are 1.02, 0.09, 0.01, 0.001 and 0.02, respectively. There is evidence of increasing returns to scale under the inorganic farming system as the elasticity of the production function with respect to the factors of production was greater than 1 (1.02+0.09+0.01+0.001+0.02 = 1.14). Given the specification of the models, the results show that the elasticity of the mean value of farm output was estimated to be an increasing function of farm size, labour, fertilisers and pesticides. The returns-to-scale parameter indicates what happens when all production resources are varied in the long run by the same proportion. However, the elasticities of the mean value of farm output under the organic farming system with respect to farm size, labour, manure and the quantity of seeds are 0.82, 0.08, 0.03 and 0.002, respectively. There is evidence of decreasing returns to scale under the organic farming system as the elasticity of the production function with respect to the factors of production was less than 1 (0.82+0.08+0.03+0.002 = 0.932). This implies that the farmers are in stage II in the production function curve. At this stage, every addition to the production inputs would lead to a less than proportionate addition to the output. This suggests that this is the most efficient stage for the farmers to operate.

Table 3. The maximum likelihood estimate of the stochastic frontier production function.

Variables	MLE inorganic	MLE organic
Efficiency function		
Farm size (ha)	1.0282*** (26.36)	0.8190*** (9.10)
Labour (mandays)	0.0955*** (3.37)	0.0830** (2.11)
Quantity of fertilisers (kg)	0.0115 (0.88)	-
Quantity of organic manure (kg)	-	0.0264* (1.94)
Quantity of seeds (kg)	0.0013*** (3.25)	0.0019*** (8.20)
Quantity of pesticides (litres)	0.0153 (1.08)	-
Constant	7.5137*** (74.32)	7.1869*** (44.59)
Inefficiency function		
Age	1.0527* (1.74)	0.5623 (1.03)
Gender	-0.0228 (-0.02)	-1.1144 (-1.4)
Marital status	0.3903 (0.61)	0.0088 (0.03)
Years of education	-2.1148*** (12.76)	-0.1957*** (-4.99)
Household size	-0.3384 (-1.08)	-0.2505* (-1.70)
Farming experience	-4.0475** (-2.46)	-0.908 (-1.02)
Constant	0.2394 (0.07)	0.0785 (0.06)
Diagnosis statistics		
Sigma-square (σ^2)	0.017 (6.35)	0.0357 (7.32)
Gamma (γ)	0.8189 (19.04)	0.7893 (4.39)
Number of observation	42	58
Wald chi2(3)	874.7	188.76
Log likelihood	-17.269848	-11.125615
Prob> chi2	0.000	0.000

Source: Field Data Analysis, 2018. Values in parentheses represent t-statistics. Note: *** implies the 1%, ** implies the 5% and * implies the 10% significance level.

The distribution of the technical efficiency scores under inorganic and organic farming systems

Table 4 presents the frequency distribution of the technical efficiency of the sampled vegetable farmers under the inorganic and organic farming systems. The technical efficiency distribution clearly shows that the technical efficiency skewed heavily in the 0.90 and 1.00 range, representing 71.4% of the sampled vegetable farmers under the inorganic farming system. The predicted technical efficiency differs among the sampled vegetable farmers under the inorganic farming system, with minimum and maximum values of 0.5274 and 0.9611, respectively and a mean technical efficiency value of 0.8957. The wide variation in technical efficiency estimates is an indication that most of the farmers use their resources inefficiently in the production process, and there are opportunities for improving their current level of technical efficiency. The distribution of the technical efficiency clearly shows that the technical efficiency skewed heavily in the 0.70 and 0.89 range, representing 50% of the sampled vegetable farmers under the organic farming system. The predicted technical efficiency differed among the sampled vegetable farmers under the organic farming system, with minimum and maximum values of 0.3360 and 0.9507, respectively and a mean technical efficiency value of 0.7564. The wide variation in technical efficiency estimates is an indication that most of the farmers use their resources inefficiently in the production process, and there are opportunities for improving their current level of technical efficiency.

It is worthy of note that there was a significant difference in the technical efficiency of farmers under the farming systems with production under the inorganic farming system significantly higher than under the organic farming system ($P < 0.01$).

Table 4. The distribution of the technical efficiency scores.

Technical efficiency scores	Inorganic		Organic	
	Frequency	Percentage (%)	Frequency	Percentage (%)
<0.5	-	-	5	8.6
0.50–0.69	2	4.8	14	24.1
0.70–0.89	10	23.8	29	50
0.90–1.00	30	71.4	10	17.2
Mean	0.8957^{α}		0.7564^{α}	
Minimum	0.5274		0.336	
Maximum	0.9611		0.9507	
N	42		58	

Source: Field Data Analysis, 2018, $^{\alpha}$ means that there is a significant difference in means.

The determinants of technical inefficiency under inorganic and organic farming systems

Table 3 reveals the analysis of the inefficiency model. The signs and significance of the estimated coefficients in the inefficiency model have important implications for the farmers' technical efficiency. A negative sign means that the variable increases efficiency, whereas a positive coefficient means a decrease in the efficiency level. The age of the farmer, years of education and farming experience significantly influenced the technical inefficiency under the inorganic farming system. The age of farmers had a significant positive relationship with the technical inefficiency at 10%. This implies that as the vegetable farmer gets older, the level of technical inefficiency will increase. This is in accordance with the findings of Bidgoli et al. (2019) that the older the farmer, the less technically efficient the farm. Years of education of the farmer had a significant negative relationship with the technical inefficiency at 1%. The negative effect of years of education indicates that technical efficiency rises with an increase in years of education since education is an important factor in recognising and seizing investment opportunities. Highly educated farmers are more likely to adopt innovations than the illiterate ones (Osinowo and Tolorunju, 2019). The coefficient of farming experience had a significant negative relationship with the technical inefficiency at 5%. This follows the a priori expectation that technical efficiency should increase with an increase in years of experience, since experience is expected to be positively correlated with the adoption of improved production technology and techniques (Ojo and Afolabi, 2000).

Furthermore, the study presents the factors that influence technical inefficiency under the organic farming system. The years of education of the farmer and household size significantly influence technical inefficiency under this farming system. The coefficient of the years of education of the farmer had a negative and significant relationship with the technical inefficiency at the 1% level of significance. This implies that as the years of education of the vegetable farmer increase, the level of technical inefficiency decreases. As established under the inorganic farming system, the more knowledgeable the farmers are, the higher their likelihood to adopt innovations. Also, the coefficient of the household size of farmers had a negative and significant relationship with the technical inefficiency at the 10% level of significance. This implies that as the number of household members increases, the level of technical inefficiency will decrease. This could be due to the fact that large household members could be used as a source of family labour which would invariably increase the technical efficiency of production. This disagrees with the results of Obayelu et al. (2016) that household size increases the technical efficiency of the farmers.

Conclusion

This study estimated the profitability and the technical efficiency of vegetable production under inorganic and organic farming systems in Owerri municipal, Imo State, Nigeria. The findings of this study concluded that both organic and inorganic vegetable productions in Owerri municipal are profitable; however, the inorganic farming system had significantly higher returns than the organic farming system.

The results have revealed that there is a wide variation in technical efficiency estimates for both systems, which indicates that most of the farmers use their resources inefficiently in the production process. There are still opportunities for improving their current level of technical efficiency. The mean technical efficiencies were 0.8957 (89.57%) and 0.7564 (75.64%) under inorganic and organic farming systems, respectively. The direct factors that increased vegetable production were farm size, labour, the quantity of manure and the quantity of seeds used under both systems. Furthermore, the age of the farmer, years of education and farming experience were the variables that significantly influenced technical inefficiency under the inorganic farming system. In contrast, the years of education of the farmer and household size significantly influenced technical inefficiency under the organic farming system.

Although the vegetable producers under the two considered farming systems are found to be technically efficient, there is a need to increase the use of variables for the efficient production of vegetables in the study area. The findings from this study have policy implication found useful for improving vegetable production in the study area. It has been established that as the vegetable farmer gets older, the level of technical inefficiency increases; therefore, policies that would attract young people to the vegetable farming business are advocated. This would lead to an increase in the production level, given that young people are more receptive to agricultural innovation than older farmers. Education is one of the policy variables which can be used to improve the current level of the agricultural technical efficiency of vegetable farmers in Nigeria. The study, therefore, suggests the formulation and implementation of agricultural policy in the country that would attract educated people to farming and also encourage illiterate farmers to undergo education or training, which would lead to an increase in the level of productivity in vegetable production. The findings of this study have confirmed that the inorganic farming system is found to be more profitable than the organic farming system; hence, farmers are encouraged to focus more on practising organic farming than inorganic farming.

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UPOREDNA ANALIZA PROFITABILNOSTI I TEHNIČKE EFIKASNOSTI DVA SISTEMA PROIZVODNJE POVRĆA U NIGERIJI

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R e z i m e

Povećanje poljoprivredne produktivnosti poboljšane raznovrsnim sistemima proizvodnje presudno je za održivu prehrambenu sigurnost i ekonomski razvoj. Cilj ove studije je da uporedi profitabilnost i tehničku efikasnost proizvodnje povrća i faktore koji utiču na tehničku efikasnost proizvodnje povrća između konvencionalnog i organskog sistema proizvodnje u Državi Imo, Nigerija. Primarni podaci prikupljeni su pomoću strukturiranih upitnika koji su obuhvatali 100 proizvođača povrća korišćenjem postupka višefaznog uzorkovanja. Budžetska analiza i model stohastičke granice proizvodnje korišćeni su za procenu profitabilnosti i tehničkih efikasnosti proizvodnje. Prosečni proizvođač ostvario je 277.445,24 ₦ odnosno 190.506,04 ₦ po hektaru kao profit od konvencionalne i organske proizvodnje povrća i potencijalno može zaraditi 4,40 ₦ odnosno 2,89 ₦ na svaku uloženu nairu. Međutim, sistem konvencionalne proizvodnje ostvario je znatno veće povraćaje nego sistem organske proizvodnje. Srednja tehnička efikasnost za organske i konvencionalne proizvođače povrća bila je 89,57%, odnosno 75,64%. Veličina gazdinstva, radna snaga i količina semena bili su presudni faktori koji su uticali na tehničku efikasnost oba sistema prozvodnje. Takođe, starost, godine obrazovanja i poljoprivredno iskustvo bile su značajne promenljive koje su uticale na tehničku neefikasnost konvencionalnih proizvođača, dok su godine obrazovanja i veličina domaćinstva značajno uticale na tehničku neefikasnost organskih proizvođača. Ova studija se zalaže za subvencionisane inpute za organske proizvođače kako bi nadoknadili niže prinose i politike koje bi privukle mlade ljude da se bave povrtarstvom radi povećanja nivoa proizvodnje.

Ključne reči: uporedna analiza, profitabilnost, stohastička granica, povrće.

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Veb sajt

Platnick, N.I. (2010). The world spider catalog, version 10.5. *American Museum of Natural History*. Retrieved February 12, 2016, from http://research.amnh.org/entomology/spiders/catalog/index.html

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Tabele

Tabele obeležene arapskim brojevima (1, 2, itd.) praćene naslovom treba da se nalaze na odgovarajućem mestu u tekstu, u fontu 9. Maksimalna širina tabela treba da bude 13 cm. One treba da budu jasne, što jednostavnije i pregledne. Treba izbegavati vertikalne crte, a broj kolona ograničiti tako da tabela ne bi bila preširoka. Takođe, treba izbegavati nepotrebnu upotrebu horizontalnih crta. Naslov tabele, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom iznad tabele. Ispod tabele treba dati detaljno objašnjenje skraćenica, simbola i znakova korišćenih u samoj tabeli. Svaka tabela mora biti pomenuta u tekstu.

Ilustracije

Svi grafikoni, dijagrami i fotografije treba da se nazovu „Slika“ (1, 2, itd.). Prilažu se na odgovarajućem mestu u tekstu. Grafikone i dijagrame treba uraditi fontom 9, u crno-beloj tehnici i sa maksimalnom širinom od 13 cm. Voditi računa da oni budu čitki i jasni i nakon redukcije veličine. Za svaki grafikon i dijagram treba obezbediti detaljnu legendu bez skraćenica. Fotografije moraju biti visokog kvaliteta da bi se tehnički mogle dobro reprodukovati. Prilažu se u „TIF“ ili „JPG“ formatu, u crno-beloj tehnici. Naslov ilustracije, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom ispod ilustracije. Svaka ilustracija mora biti pomenuta u tekstu.

Skraćenice i jedinice

U radu treba koristiti samo standardne skraćenice. Merne jedinice treba izražavati u internacionalnom sistemu jedinica (SI). Kod navođenja jedinica posle broja treba da stoji razmak (osim za % i °C). Skraćenice se mogu koristiti i za druge izraze pod uslovom da se ti izrazi navedu u punom obliku prilikom prvog pominjanja, sa skraćenim oblikom u zagradi. Vrednosti od 1 do 9 mogu se izražavati slovima, a ostali brojevi isključivo numerički.

Nomenklatura
Celokupna nomenklatura (hemijska i biohemijska, taksonomska, genetička itd.) mora biti usklađena sa međunarodnim kodeksima i komisijama, kao što su *International Union of Pure and Applied Chemistry, IUPAC-IUB Combined Commission on Biochemical Nomenclature, Enzyme Nomenclature, International Code of Botanical Nomenclature, International Code of Nomenclature of Bacteria* itd.

Formule
Sve formule i jednačine u radu moraju biti urađene pomoću programa „Word Equation“. Pri pisanju formula, radi preglednosti, ostaviti dovoljno praznog prostora oko same formule. Subskripti i superskripti treba da budu jasni. Prilikom pisanja jednačina treba dati smisao svih simbola odmah posle jednačine u kojoj se simbol prvi put koristi. Jednačine treba da budu numerisane arapskim brojevima, serijski u zagradama, na desnoj strani linije. Svaka jednačina mora biti pomenuta u tekstu kao Eq. (1), Eq. (2), itd.

Nakon objavljivanja rada, autoru za kontakt će biti poslat jedan primerak časopisa.
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