UDC: 63 ISSN 1450-8109

# JOURNAL OF AGRICULTURAL SCIENCES BELGRADE

**Vol. 65, No. 1, 2020**

**Published by University of Belgrade**
**Faculty of Agriculture**
**Republic of Serbia**

UDC: 63 ISSN 1450-8109

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Journal of Agricultural Sciences www.joas.agrif.bg.ac.rs
J. Agric. Sci.



PUBLISHED BY

University of Belgrade-Faculty of Agriculture
11081 Belgrade-Zemun, Nemanjina 6, PO Box 14, Serbia
Tel: + 381 11 4413-555/467; Fax: + 381 11 2193-659; E-mail: redakcija@agrif.bg.ac.rs
URL: http://www.agrif.bg.ac.rs/

DTP Service: Snežana Spirić

Printed by the Faculty of Agriculture, Belgrade-Zemun
Circulation: 100

Publishing is supported by the Ministry of Education, Science and Technological Development
of the Republic of Serbia, Belgrade

According to the opinion of the Ministry of Science of the Republic of Serbia
No. 413-00-1928/2001-01 dated November 6, 2001 this
Journal is exempt from general tax liability

Frequency: Four times per year

Abstracting and Indexing
CAB Abstracts, AGRICOLA, SCIndeks, EBSCO

Number of institutions the Journal is exchanged with: 80

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE
Vol. 65, No. 1, 2020

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https://doi.org/10.2298/JAS2001001M
UDC: 631.422:539.163(497.11)
631.448(497.11)
Review paper

# A REVIEW: NATURAL AND ARTIFICIAL RADIONUCLIDES AND RADIATION HAZARD PARAMETERS IN THE SOIL OF MOUNTAIN REGIONS IN SERBIA

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**Abstract:** This review paper discusses the content of natural ($^{40}$K, $^{238}$U, $^{226}$Ra, and $^{232}$Th) and artificial ($^{137}$Cs) radionuclides in the soil of the mountains of Maljen, Tara and Kopaonik in the Republic of Serbia over 2002–2015. In addition, the paper gives radiation hazard parameters, i.e., radium equivalent activity, absorbed dose rate, annual effective dose equivalent, external hazard index, annual gonadal dose equivalent, and excess lifetime cancer risk outdoors that we calculated from the obtained content of the natural radionuclides in the soil samples. We compared the parameters to previously published results for different parts of the country and looked into the radioecological status of the investigated areas.

**Key words:** soil, radionuclides, gamma spectrometry, radiation hazard parameters, mountain region.

## Introduction

Ionizing radiation and radioactivity are an integral part of the environment. Natural radionuclides, characterized by a long half-life, are present in rocks, minerals and soil. These primordial terrestrial radionuclides are divided into two groups.

The first group includes three natural decay series, headed by $^{238}$U, $^{232}$Th and $^{235}$U, and their decay products (Atwood, 2010), which are alpha, beta and gamma emitters. In nature, uranium is present as a mixture of $^{238}$U (99%, half-life $4.5 \times 10^9$ years), $^{235}$U (0.71%, half-life $7.034 \times 10^8$ years), and $^{234}$U (0.006%, half-life $2.46 \times 10^5$ years). Thorium-232 (half-life $1.41 \times 10^{10}$ years) is less radioactive than uranium but

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more abundant in nature. The most important radioactive decay isotopes are: $^{226}$Ra (half-life 1602 years) that belongs to the $^{238}$U series, and $^{228}$Ra (half-life 5.7 years) from the $^{232}$Th series. A daughter nuclide of $^{228}$Ra is a radioactive gas radon, which contributes the largest dose to the radiation from natural radioactive sources.

Radionuclides in the second group are $^{40}$K and $^{87}$Rb. Potassium-40 (half-life 1.25x10$^{9}$ years) is a radioactive isotope (contributing 0.012%) of potassium that is abundant in nature. Rubidium-87 (half-life 4.88x10$^{10}$ years) is more abundant in nature (27.83%) than $^{40}$K. These two radionuclides present in the soil significantly contribute to the total dose of irradiation to humans and biota (Fisenne, 1993).

An important source of human exposure to radiation is the decay of naturally occurring radionuclides in the soil. Radionuclides are not uniformly distributed; their concentration depends on geographic location, the geological origin of the soil, but also anthropogenic activities. All of these factors contribute to the variation of radiation exposure. According to the UNSCEAR report (2008), the average value of worldwide exposure due to the natural radiation sources is 2.4 mSv/y, with a range of 1–10 mS/y. The population receives the highest radiation doses due to the inhalation exposure to $^{222}$Rn (1.15 mSv/y), from external terrestrial radiation (0.48 mSv/y), cosmic radiation and cosmogenic radionuclides (0.39 mSv/y), and ingestion of $^{40}$K and radionuclides from the uranium and thorium series (0.29 mSv/y).

Materials containing naturally occurring radionuclides and their radioactive decay products that are not disturbed by human activities are called Naturally Occurring Radioactive Material (NORM) (IAEA, 2003). Some activities, such as mining, oil and gas production, coal combustion, use of fertilizers and release of fertilizer production wastes may lead to concentrated NORM materials.

The environmental contamination of Serbia with a fission radionuclide $^{137}$Cs (half-life 30 years) is a consequence of the nuclear accident in Chernobyl (in 1986) and nuclear weapons testing in the atmosphere. The $^{137}$Cs activity concentration in different regions of the former Republic of Yugoslavia ranged between 1 kBq/m$^2$ and 10 kBq/m$^2$, depending on the prevailing meteorological conditions during the release (EU Commission, 1991). Due to its long half-life, $^{137}$Cs can still be found in the environment, especially in the soil and bioindicator organisms, such as mosses, fungi, blueberries and wild animals (Steinnes and Njåstad, 1993; Delfanti et al., 1999; Čučulović et al., 2012; Mitrović et al., 2013b, 2014a, 2016c; Todorović et al., 2013). The retention of $^{137}$Cs in the soil depends on the soil physico-chemical characteristics and its clay content, but also on the climate, surrounding vegetation, etc. (Cremers et al., 1988; Rosén et al., 1999; Fujii et al., 2014).

Our paper gives a review of the activity concentration of natural ($^{40}$K, $^{238}$U, $^{226}$Ra, and $^{232}$Th) and artificial ($^{137}$Cs) radionuclides in the soil from the mountains of Tara, Maljen and Kopaonik, with an emphasis given to estimating the radiation hazard parameters.

## Materials and Methods

The soil samples were collected over 2002–2015 in the areas of the mountains of Maljen, Tara, and Kopaonik (Figure 1). The mountains of Tara and Kopaonik are nature parks and thus all their reserves are under the state protection. The studied areas present some of favorite tourist destinations for sports and recreation.


Figure 1. A view of Serbia with the location of the mountains of Maljen, Tara and Kopaonik.

The soil samples were collected from the surface down to a depth of 20 cm. In the laboratory, the samples were crushed, dried at 105 °C, sieved, homogenized and put into Marinelli beakers (0.5 ml and 1 l). All samples were hermetically sealed and stored for 21 days to ensure equilibrium between $^{226}Ra$ and its daughters.

We used gamma-ray spectrometric measurements on High Purity Germanium detectors (ORTEC and Canberra), with a relative efficiency of 18%, 20% and 30%, and an energy resolution of 1.85 keV (1332.5 $^{60}Co$), to determine the activity concentrations of the investigated radionuclides.

The analysis of each measured gamma-ray spectrum was performed by a software program GAMMA VISION-32. All obtained results are expressed as (mean ± standard deviation).

The activity concentrations of $^{40}K$ and $^{137}Cs$ were derived directly from their 1460.8 keV and 661.66 keV gamma energies, respectively. For other radionuclides, we included the following steps in the analysis:

– We assumed equilibrium conditions between the parent nuclide $^{238}$U and its daughters, $^{234}$Th (63.2 keV) and $^{234m}$Pa (1001 keV).

– We obtained the $^{226}$Ra activity concentration from the gamma energy of 186.1 keV corrected for $^{235}$U, and $^{226}$Ra daughters in equilibrium, $^{214}$Bi (609.3 keV, 1120.2 keV and 1764.5 keV) and $^{214}$Pb (351.9 keV).

– We used three photo peaks of $^{228}$Ac (338 keV, 911.2 keV, and 969 keV) for the activity concentration of $^{232}$Th.

Calculation of radiation hazard parameters

*Radium equivalent activity*

Since the distribution of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the soil is not uniform, we used radium equivalent activity ($Ra_{eq}$) to compare the specific activity of materials with different amounts of $^{226}$Ra, $^{232}$Th, and $^{40}$K. The definition of $Ra_{eq}$ is based on an assumption that 370 Bq/kg of $^{226}$Ra, 259 Bq/kg of $^{232}$Th, and 4810 Bq/kg of $^{40}$K produce the same gamma dose rate. We calculated $Ra_{eq}$ using (Beretka and Mathew, 1985):

$$Ra_{eq}\ (\text{Bq/kg}) = C_{\text{Ra}} + 1.43C_{\text{Th}} + 0.077C_{\text{K}} \quad (1)$$

where $C_{\text{Ra}}$, $C_{\text{Th}}$, and $C_{\text{K}}$ are the activity concentrations of $^{226}$Ra, $^{232}$Th, and $^{40}$K (in Bq/kg), respectively.

*Absorbed dose rate*

We converted the mean activity concentrations of $^{226}$Ra, $^{232}$Th, and $^{40}$K into absorbed dose rate ($\dot{D}$) using conversion factors under an assumption that all decay products of $^{226}$Ra and $^{232}$Th are in equilibrium with their precursors (UNSCEAR, 2008):

$$\dot{D}\ (\text{nGy/h}) = 0.462C_{\text{Ra}} + 0.604C_{\text{Th}} + 0.042C_{\text{K}} \quad (2)$$

*Annual effective dose equivalent*

To estimate the annual effective dose equivalent (*AEDE*), the conversion coefficient from the absorbed dose in the air to the effective dose must be considered. We used the absorbed dose rate data (Eq. 2), adopted the conversion factor of 0.7 Sv/Gy (UNSCEAR, 2008), and assumed that on average, people in Serbia spend 20% of their time outdoors, and thus obtained:

$$AEDE\ (\mu\text{Sv/y}) = \dot{D}\ (\text{nGy/h}) \times 24\ (\text{h}) \times 365\ (\text{days}) \times 0.7\ (\text{Sv/Gy}) \times 0.2 \quad (3)$$

*External hazard index*

Beretka and Mathew (1985) defined the external hazard index ($H_{ex}$) as:

$$H_{ex} = C_{\text{Ra}}/370 + C_{\text{Th}}/259 + C_{\text{K}}/4810 \quad (4)$$

For $H_{ex}$ values less than one, the radiation hazard is insignificant. The external hazard index equal to one corresponds to the upper limit of radium equivalent activity (370 Bq/kg).

*Annual gonadal dose equivalent*

We used the following equation (Arafa, 2004) to calculate annual gonadal dose equivalent (*AGDE*) to the population arising from the presence of naturally occurring radionuclides $^{226}Ra$, $^{232}Th$, and $^{40}K$ in the soil:

$$AGDE\ (\mu Sv/y) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_{K} \quad (5)$$

*Excess lifetime cancer risk outdoors exposure*

Excess lifetime cancer risk outdoors exposure ($ELCR_{outdoor}$) gives the probability of developing cancer over a lifetime at a given exposure level. We calculated $ELCR_{outdoor}$ using (UNSCEAR, 2000; ICRP, 1990):

$$ELCR_{outdoor} = AEDE \times DL \times R_f \quad (6)$$

where *DL* is the duration of life (70 years average) and $R_f$ is the risk factor (in Sv), i.e. fatal cancer risk per sievert. For stochastic effects, we used $R_f$ = 0.05 mSv for the whole population (ICRP, 2007).

## Results and Discussion

Mountains are complex ecological and very sensitive ecosystems. The characteristics of mountain ecosystems vary depending on altitude, climate conditions, geological characteristics, biomes, water flows, etc. Any changes in biotic or abiotic elements can cause an interruption in the ecosystem.

Specific activities of natural radionuclides in the soil depend on geological and geographical characteristics of a given region. In the mountain regions of Maljen, Tara and Kopaonik, serpentine soils are present. Characteristics of this soil type are extremely stressful for plant growth (Kostić et al., 1998; Vicić et al., 2014) – since they are susceptible to erosion, and often shallow and rocky, vegetation is usually sparse and poor (Tatić and Veljović, 1991; Jakovljević et al., 2001; Stevanović et al., 2003). The geological background of Mt. Kopaonik is represented by granites, serpentinites, slates, marbles, andesites, and limestones. The differences in geological characteristics between the investigated mountains also affect the content of radionuclides in the soil, which will be summarized below.

The presence of anthropogenic radionuclides, such as $^{137}Cs$, is mainly a consequence of the nuclear accident in Chernobyl in 1986. The ensuing soil contamination was a result of a number of factors, such as a distance from the accident location, rainfall index, and soil characteristics (UNSCEAR, 2000).

The mountain of Maljen

Maljen is a mountain located in the west of Serbia. It spreads in the east-west direction for approximately 25 km. The highest peak is Kraljev sto (elevation – 1100 m a.s.l.). The geologic structure of Mt. Maljen consists of ultrabasic rocks (peridotites and serpentinized peridotites). Magnesium oxide present in the soil makes this area unfavorable for plant survival (Tatić and Veljović, 1991).

The soil samples from Mt. Maljen were collected at four altitudes over 2002–2007 (Mitrović et al., 2009). Table 1 gives the gammaspectrometric results.

Table 1. $^{40}$K, $^{238}$U, $^{226}$Ra, $^{232}$Th, and $^{137}$Cs activity concentrations in the soil collected at Mt. Maljen (Bq/kg)[a].

| Altitude (m) | $^{40}$K | $^{238}$U | $^{226}$Ra | $^{232}$Th | $^{137}$Cs |
|---|---|---|---|---|---|
| 200 | 450 ± 5 | 61 ± 6 | 54 ± 5 | 57 ± 2 | 19 ± 1 |
| 650 | 394 ± 5 | 46 ± 3 | 51 ± 5 | 42 ± 2 | 47 ± 1 |
| 1000 | 70 ± 2 | 11 ± 1 | 11 ± 1 | 8 ± 1 | 64 ± 2 |
| 1100 | 102 ± 1 | 14 ± 1 | 13 ± 1 | 11 ± 1 | 259 ± 1 |
| Average | 254 | 33 | 33 | 29 | 97 |

[a]Mitrović et al. (2009).

The mean activity concentrations of the radionuclides on Mt. Maljen were 254 Bq/kg for $^{40}$K, 33 Bq/kg for $^{238}$U, 33 Bq/kg for $^{226}$Ra, 29 Bq/kg for $^{232}$Th, and 97 Bq/kg for $^{137}$Cs (Table 1). According to the UNSCEAR report (2000), the world average activity concentrations in the soil are 420 Bq/kg, 33 Bq/kg, 32 Bq/kg, and 45 Bq/kg for $^{40}$K, $^{238}$U, $^{226}$Ra, and $^{232}$Th, respectively. Our results showed that the content of natural radionuclides at lower altitudes was above the world average values. However, as altitude increased, the activity of natural radionuclides in the soil decreased by a factor of 4–6. This finding can be explained by different geochemical characteristics of the soil at different altitudes, and by the fact that soils in lower areas are generally subject to agro-technical measures and use of fertilizers based on phosphate and potassium (Bolca et al., 2007).

In contrast to this finding, there was a several-fold increase in the $^{137}$Cs activity concentration from an altitude of 200 m (19 Bq/kg) to 1100 m (259 Bq/kg), which could be explained by an increased amount of rainfall at higher altitudes after the Chernobyl accident. Contamination of the soil with $^{137}$Cs is a starting point for transfer of this radionuclide to plants and onwards through the food chain. Its presence was detected in mosses, mushrooms, game meat and milk of animals from the test sites (Mitrović et al., 2009). The highest content of $^{137}$Cs was found in sheep meat (45.8 Bq/kg) and goat milk (24.1 Bq/kg) sampled from animals grazing at 1000 m a.s.l.

Based on the measured activity concentrations of natural radionuclides in the soil (Table 1), we calculated radiation hazard parameters for Mt. Maljen (Table 2). The radium equivalent activity was below 170 Bq/kg (Table 2). For comparison, a value of 370 Bq/kg is the criterion limit for $Ra_{eq}$ in building materials (Beretka and Mathew, 1985), and its corresponding annual effective dose equivalent is 1 mSv, which, in turn, represents the dose limit for the general population. Further, the locations at lower altitudes showed an absorbed dose rate higher than the world average of 59 nGy/h (UNSCEAR, 2008). The calculated annual effective dose equivalents at lower altitudes were also higher than the world mean of 70 µSv/y (UNSCEAR, 2000), while the annual gonadal dose equivalent values were lower than the level of 1 mSv/y, which is a recommended limit by the International Commission on Radiological Protection (2007) for the general public. According to UNSCEAR (2000), the gonads, bone marrow, and bone surface are considered as the organs of importance since they are active. The probability of cancer incidence in a population during the lifetime due to an exposure to natural radionuclides ($ELCR_{outdoor}$) in the soil at lower altitudes was slightly higher than the world average value of $0.29 \times 10^{-3}$ (UNSCEAR, 2000), but the mean $ELCR_{outdoor}$ value was lower ($0.20 \times 10^{-3}$).

Table 2. Radiation hazard parameters for the soil collected at Mt. Maljen.

| Altitude (m) | $Ra_{eq}$ (Bq/kg) | $\dot{D}$ (nGy/h) | *AEDE* (µS/y) | $H_{ex}$ | *AGDE* (µSv/y) | $ELCR_{outdoor}\ x10^{-3}$ |
|---|---|---|---|---|---|---|
| 200 | 169 | 78 | 95 | 0.46 | 544 | 0.36 |
| 650 | 141 | 65 | 80 | 0.38 | 455 | 0.30 |
| 1000 | 27 | 13 | 16 | 0.07 | 88 | 0.06 |
| 1100 | 37 | 17 | 21 | 0.10 | 120 | 0.08 |
| Average | 94 | 43 | 53 | 0.25 | 302 | 0.20 |
| Average world values | 370[a] | 59[b] | 70[c] | ≤ 1[d] | 1000[e] | 0.29 x10$^{-3)}$[f] |

[a]Beretka and Mathew (1985); [b]UNSCEAR (2008); [c]UNSCEAR (2000); [d]ICRP (2000); [e]ICRP (2007); [f]UNSCEAR (2000).

As a summary of the above results, the obtained external hazard index for altitudes above 200 m was less than one (Table 2), i.e., less than the limit recommended by ICRP (2000), implying that the investigated area is radioecologically safe to use.

The mountain of Tara

Farther west and south from Maljen is the mountain of Tara. It covers an area of 250 km$^2$ and geologically belongs to the Dinarides. The highest peak is Kozji rid (1591 m a.s.l.). The climate is distinctly mountainous, and the winter period is cold with plenty of snow. The soil is mainly uncultivated, dominated by the forest ecosystem (80%). The soil is composed of various limestones ($MgCO_3$, $CaCO_3$) and shale (Si) rocks. Forests mainly consist of beech, spruce and fir.

Table 3 gives the activity concentrations of radionuclides in the soil of Mt. Tara, while Table 4 shows the calculated radiation hazard parameters. In all soil samples, the activity concentrations of natural radionuclides were below the world average (Table 3), except the altitude of 1100 m where the content of $^{238}$U, $^{226}$Ra, and $^{232}$Th was higher (Djurić et al., 1996; Mitrović et al., 2009; Rakić et al., 2014). The obtained results showed that the level of natural radionuclides' activity in non-cultivated soil of the mountains of Maljen and Tara was similar (Tables 1 and 3). Popović et al. (2009) reported that the mean activities of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the soil from Mt. Tara collected over a period of 1983–1993 were 42 Bq/kg (22–92 Bq/kg), 46 Bq/kg (24–69 Bq/kg) and 613 Bq/kg (356–1126 Bq/kg), respectively. Differences in radionuclides' content in the soil are a consequence of soil type. For example, higher activity concentrations of $^{40}$K, $^{238}$U, and $^{232}$Th can be found in shale soils than in the soil composed mainly of limestone rocks (Djurić et al., 1996).

Table 3. $^{40}$K, $^{238}$U, $^{226}$Ra, $^{232}$Th and $^{137}$Cs activity concentrations in the soil collected at Mt. Tara (Bq/kg).

| Altitude (m) | $^{40}$K | $^{238}$U | $^{226}$Ra | $^{232}$Th | $^{137}$Cs | Reference |
|---|---|---|---|---|---|---|
| 300 | 420 ± 25 | 34 ± 3 | / | 43 ± 3 | / | Djurić et al. (1996) |
| 1000 | 72 ± 3 | 11 ± 1 | 11 ± 1 | 8.3 ± 0.4 | 91 ± 4 | Mitrović et al. (2009) |
| 1000 | 368 ± 37 | 30 ± 2 | / | 31 ± 3 | / | Djurić et al. (1996) |
| 1082 (Site 1) | 143 ± 10 | / | 23 ± 3 | / | 221 ± 6 | Rakić et al. (2014) |
| 1082 (Site 2) | 237 ± 10 | / | 14 ± 1 | / | 189 ± 6 | Rakić et al. (2014) |
| 1100 | 395 ±11 | 50 ± 5 | 50 ± 5 | 49 ± 2 | 104 ± 8 | Mitrović et al. (2009) |
| Average | 300 | 31 | 31 | 30 | 98 | |

The values of radiation hazard parameters on all sample locations were below the recommended maximum values (Tables 2 and 4). The exception again was the soil collected at 1100 m a.s.l. where absorbed dose rate ($\dot{D}$), annual effective dose equivalent (*AEDE*) and excess lifetime cancer risk ($ELCR_{outdoor}$) were about 1.2-fold higher than the recommended levels.

Table 4. Radiation hazard parameters for the soil collected at Mt. Tara.

| Altitude (m) | $Ra_{eq}$ (Bq/kg) | $\dot{D}$(nGy/h) | *AEDE* (μSv/y) | *Hex* | *AGDE* (μSv/y$^1$) | $ELCR_{outdoor}$x10$^{-3}$ |
|---|---|---|---|---|---|---|
| 1000 | 28 | 13 | 16 | 0.08 | 91 | 0.06 |
| 1100 | 150 | 69 | 85 | 0.41 | 483 | 0.32 |
| Average | 89 | 41 | 51 | 0.24 | 287 | 0.19 |

Anthropogenic $^{137}$Cs was also detected in the soil (Table 3). In 1991, five years after the Chernobyl accident, the activity concentration of this radionuclide in the surface layers was significantly lower in limestone soils (88 Bq/kg) than in shale soils (462 Bq/kg) (Djurić et al., 1996; Popović et al., 1996; Popović and Spasić, 2006; Popović et al., 2009), and it is still present in the soil (Rakić et al., 2014).

Transfer of this radioisotope from the soil to plants strongly depends on the soil type and characteristics of the plant species. The study by Mitrović et al. (2009) showed that radiocesium was present in the food chain: soil-plants-animals. Between 2002 and 2007, the medium activity concentration of $^{137}$Cs was 5.1 Bq/kg in the grass, 2.9 Bq/kg in sheep milk, and 6.5 Bq/kg in sheep meat. Small ruminants, such as sheep and goats, are good bioindicators for radiocesium contamination of the environment, because the ingestion of soil can be a major source of radiocontamination for free-grazing ruminants (Assimakopoulos et al., 1993).

After the Chernobyl accident, the activity concentrations of $^{134}$Cs and $^{137}$Cs in herbal teas from Serbia reached 5000 Bq/kg (Petrović, 2010), but results obtained 28 years later showed a significant reduction in the $^{137}$Cs concentration in teas from mountain regions (Mitrović et al., 2014). In herbal teas collected from Mts Maljen and Tara, high activity concentrations of $^{137}$Cs (77 Bq/kg and 73 Bq/kg, respectively) were observed in plant species *V. myrtillus* (bilberry). Some organisms, e.g. bilberry but also mosses, mushrooms and game, are good bioindicators of environmental pollution with radiocesium (Grdović et al., 2010; Mitrović et al., 2013, 2016a,b; Rakić et al., 2014).

The mountain of Kopaonik

The south-western part of Serbia is dominated by Kopaonik, which is one of the highest mountain ranges in the country. It extends in the northwest-southeast direction for 80 km, and has a width of around 40 km in the middle. The highest peak is Pančićev vrh (elevation – 2017 m a.s.l.). The Kopaonik National Park covers an area of about 12000 ha, and it is a very popular tourist destination. The climate is subalpine with the annual average precipitation rate up to 1000 mm.

The results of gamma spectrometric determination of radionuclides in the soil collected on nine locations at Mt. Kopaonik during 2013–2016 (Mitrović et al., 2014, 2016; Džoljić et al., 2017) and radiation hazard parameters are presented in Tables 5 and 6, respectively.

The mean activity concentrations of radionuclides at Mt. Kopaonik were 723 Bq/kg for $^{40}$K, 78 Bq/kg for $^{238}$U, 75 Bq/kg for $^{226}$Ra, and 76 Bq/kg for $^{232}$Th (Table 5), which is two-fold higher than the world average activity concentrations of these radionuclides in the soil (UNSCEAR, 2000). The obtained differences between the results can be attributed to the geological structure at the sampling locations. For example, at Lisina, a sampling site with an elevation of 1300 m, the geological period belongs to the Palaeozoic, and rocks are comprised of granite, granodiorite and quartz, known for its high content of radionuclides. On the other hand, higher up at Gobelja, metamorphic rocks (crystalline shales) are found. Furthermore, the results showed an increase of natural radionuclides $^{238}$U, $^{226}$Ra, and $^{232}$Th with altitude. An exception was the Đerekare location where somewhat higher radionuclide content was detected.

Table 5. $^{40}$K, $^{238}$U, $^{226}$Ra, $^{232}$Th and $^{137}$Cs activity concentrations in the soil collected at Mt. Kopaonik (Bq/kg).

| Sampling site | Altitude (m) | $^{40}$K | $^{238}$U | $^{226}$Ra | $^{232}$Th | $^{137}$Cs |
|---|---|---|---|---|---|---|
| Brus[a] | 429 | 526 ± 16 | 27 ± 4 | 29 ± 2 | 32 ± 2 | 31 ± 1 |
| Jošanička banja[a] | 557 | 269 ± 8 | 33 ± 4 | 29 ± 3 | 32 ± 6 | 142 ± 4 |
| Đerekare[a] | 950 | 920 ± 27 | 70 ± 6 | 78 ± 6 | 89 ± 7 | 6.0 ± 0.2 |
| Brzeće[a] | 980 | 620 ± 19 | 33 ± 5 | 34 ± 4 | 36 ± 3 | 32 ± 1 |
| Brezeće[b] | 1100 | 650 ± 40 | 37 ± 5 | 30 ± 3 | 41 ± 3 | 89 ± 5 |
| Lisina[a] | 1300 | 730 ± 21 | 184 ± 10 | 174 ± 10 | 133 ± 5 | 79 ± 2 |
| Suvo Rudište[b] | 1700 | 780 ± 50 | 93 + 8 | 88 ± 6 | 111 ± 7 | 9.8 ± 0.8 |
| Gobelja[a] | 1934 | 722 ± 21 | 62 ± 5 | 65 ± 4 | 63 ± 2 | 30 ± 1 |
| Pančićev vrh[a] | 2017 | 1291 ± 39 | 160 ± 10 | 152 ± 11 | 151 ± 9 | 4.2 ± 0.2 |
| Average | | 723 | 78 | 75 | 76 | 47 |

[a]Mitrović et al. (2016); [b]Džoljić et al. (2017).

Mt. Kopaonik was under a prolonged attack during the NATO action against the Federal Republic of Yugoslavia in 1999. The bombing led to the destruction of the terrain and disruption of the forest ecosystem (UNEP/UNCHS BTF, 1999). The gammaspectrometric analysis of the soil taken from the Gobelja location where severe bombing activity took place, showed that activity concentrations of $^{238}$U and $^{226}$Ra were in equilibrium, implying a natural origin of the radionuclides (Mitrović et al., 2016). This study, however, did not investigate soil samples from the bombing craters. The average activity concentration of $^{137}$Cs (47 Bq/kg) on Mt. Kopaonik was two-fold lower than on Mt. Maljen (97 Bq/kg) and Mt. Tara (98 Bq/kg). These variations can be explained by a different deposition of Chernobyl radiocesium, differences in forest type (Koarashi et al., 2016), physical and chemical properties of soils (Korashi et al., 2012), as well as the sedimentary structure of this location (Mitrović et al., 2016).

The radium equivalent activity in the soil was mostly below 370 Bq/kg (Table 6). The exceptions were the locations of Lisina and Pančićev vrh where $Ra_{eq}$ exceeded this limit (415 Bq/kg and 458 Bq/kg, respectively). As a consequence of the high activity concentration of natural radionuclides in the soil, the values of absorbed dose rate ($\dot{D}$) and annual effective dose equivalent (*AEDE*) were higher than the global average of 58 nGy/h (UNSCEAR, 2008) and 70 μSv/y (UNSCEAR, 2000), respectively. However, at lower altitudes, in Brus and Jošanička banja, these two parameters were below the global means (Table 6).

Table 6. Radiation hazard parameters for the soil collected in Mt. Kopaonik.

| Sampling site | Altitude (m) | $Ra_{eq}$ (Bq/kg) | $\dot{D}$ (nGy/h) | *AEDE* (μSv/y) | *Hex* | *AGDE* (μSv/y) | $ELCR_{outdoor}$x$10^{-3}$ |
|---|---|---|---|---|---|---|---|
| Brus[a] | 429 | 115 | 55 | 67 | 0.31 | 389 | 0.25 |
| Jošanička banja[a] | 557 | 95 | 44 | 54 | 0.26 | 308 | 0.20 |
| Đerekare[a] | 950 | 276 | 128 | 158 | 0.75 | 902 | 0.59 |
| Brzeće[a] | 980 | 133 | 63 | 78 | 0.36 | 450 | 0.29 |
| Brezeće[b] | 1100 | 139 | 66 | 81 | 0.37 | 468 | 0.31 |
| Lisina[a] | 1300 | 420 | 191 | 235 | 1.14 | 1323 | 0.89 |
| Suvo Rudište[b] | 1700 | 307 | 140 | 172 | 0.83 | 981 | 0.65 |
| Gobelja[a] | 1934 | 211 | 98 | 121 | 0.57 | 691 | 0.46 |
| Pančićev vrh[a] | 2017 | 467 | 216 | 264 | 1.26 | 1506 | 1.00 |
| Average | | 240 | 111 | 137 | 0.65 | 780 | 0.52 |

[a]Mitrović et al. (2016); [b]Džoljić et al. (2017).

In all locations except Lisina and Pančićev vrh, the annual gonadal dose equivalent (*AGDE*) values were lower than 1 mSv/y. Similarly, the average value for the external hazard index ($H_{ex}$) was less than one (Table 6). Still, values higher than 1 were recorded in Lisina and Pančićev vrh. The probability of cancer incidence in a population during the lifetime due to an exposure to natural radionuclides in the soil ($ELCR_{outdoor}$) at higher altitudes was higher than the world average value of 0.29x$10^{-3}$ (UNSCEAR, 2000).

In addition to the natural radionuclides, the artificial $^{137}$Cs was detected in the soil, grass, spruce, cow milk and moss samples from Mt. Kopaonik (Mitrović et al., 2016; Džoljić et al., 2017). In the soil, the lowest activity concentration of $^{137}$Cs was recorded in the area of Pančićev vrh, and the maximum in Jošanjička banja (Table 5). A decrease in the $^{137}$Cs content in the soil with an increasing altitude is probably due to stronger soil erosion at higher altitudes (Nešić et al., 2009).

## Radionuclides in the soil of Serbia

Determination of radionuclides' content in the soil has been a subject of many studies with the purpose of risk assessment and protection of the humans, non-human biota and the environment from radioactive pollution. Studies performed by Momčilović et al. (2010) and Tanič et al. (2014) in the area of an abandoned uranium mine (Grabovnica mine) at Mt. Stara Planina showed that the terrestrial gamma dose rate due to $^{238}$U (31–237 Bq/kg), $^{232}$Th (6–109 Bq/kg), and $^{40}$K (64–

977 Bq/kg) in the soil was two-fold higher than that of the surrounding area. In the vicinity of the mine compounds, the radionuclide content was within the usual range for this mountain or slightly higher. In a part of Mt. Stara Planina farther south, at sampling points of Smilovci, Smilovsko jezero, Kamenica, and Gornji Krivodol, the activity concentrations of natural radionuclides in the soil were lower and ranged between 393 Bq/kg and 543 Bq/kg, 29 Bq/kg and 57 Bq/kg, 25 Bq/kg and 51 Bq/kg, and 28 Bq/kg and 69 Bq/kg for $^{40}$K, $^{238}$U, $^{226}$Ra, and $^{232}$Th, respectively (Vranješ et al., 2016). Apart from the natural radionuclides, $^{137}$Cs was also detected in the environment of Mt. Stara Planina, i.e. in the soil, mosses and medicinal plants (Vranješ et al., 2016).

Gammaspectrometric determination of radionuclides present in the soil from Mt. Zlatibor (Dragović et al., 2010a) showed that the content of $^{40}$K ranged between 212 Bq/kg and 740 Bq/kg, $^{238}$U between 10.6 Bq/kg and 69.0 Bq/kg, $^{226}$Ra between 8.3 Bq/kg and 87.5 Bq/kg, $^{232}$Th between 10.4 Bq/kg and 41.4 Bq/kg, and $^{137}$Cs between 73 Bq/kg and 155 Bq/kg. This study showed enrichment of $^{226}$Ra with respect to $^{238}$U in some soil samples, probably due to greater mobility of uranium, which, in turn, led to a depleted content of this element relative to radium. In Mt. Zlatibor, anthropogenic $^{137}$Cs was detected in bioindicators, as well as ants, mosses, lichens (Dragović et al., 2010a,b) and medicinal plants (Mitrović et al., 2013, 2014, 2016).

Investigation of radionuclide content in the soil has also been conducted in urban areas (Grdović et al., 2010; Janković Mandić and Dragović, 2010; Dragović et al., 2012; Milenković et al., 2015; Mitrović et al., 2016b; Vukašinović et al., 2018), agriculture soil (Vukašinović et al., 2009, 2010; Bikit et al., 2011; Mitrović et al., 2013b; Forkapić et al., 2017) and in the vicinity of industrial plants (Vitorović et al., 2012; Vukašinović et al., 2014). Gammaspectrometric determination of $^{238}$U in the soil sampled from 21 different locations in Serbia and Montenegro showed that uranium content ranged from 1.28 ppm on Slatina (approximately 15.7 Bq/kg) to 4.80 ppm in Vranje (approximately 58.8 Bq/kg), with the mean value of 2.76 ppm (approximately 33.8 Bq/kg) (Dragović et al., 2006b). The absorbed gamma dose rates ($\dot{D}$) ranged between 24.5 nGy/h and 97.6 nGy/h, with the mean of 66.8 nGy/h, annual effective dose equivalent (*AEDE*) varied from 42.3 μSv/y to 119 μSv/y, with the mean of 81.9 μSv/y (Dragović et al., 2006a); and the radiation hazard was insignificant for population living in the investigated areas.

It is also worth noting that many studies have been conducted to determine the uranium content in various environmental samples from locations where depleted uranium ammunition was used during the NATO bombing in 1999 (Miljević et al., 2001; Esposito et al., 2002; Popović et al., 2008, 2010; Sarap et al., 2014). These locations are now included as an integral part of the monitoring program at the territory of the Republic of Serbia (Official Gazette RS, 2010).

## Conclusion

Determining natural radioactivity in the soil is a necessary step in the evaluation of the radiation hazard parameters. The average values of activity concentrations of $^{238}U$, $^{226}Ra$ and $^{232}Th$ at Mts Maljen and Tara were within the range of values obtained for other parts of Serbia and worldwide (UNSCEAR, 2008). However, the measured concentrations were approximately two-fold higher at Mt. Kopaonik.

The radiation hazard parameters obtained for Mts Maljen and Tara were similar to values reported for other parts of Serbia implying that the investigated areas were radioecologically safe for humans.

Mt. Kopaonik showed the average values of absorbed dose rate, annual effective dose equivalent and external hazard index two-fold higher than at Mts Maljen and Tara. At two particular locations, Lisina and Pančićev vrh, the values of absorbed dose rate and annual effective dose equivalent were about four-fold higher than those on Mts Maljen and Tara. External hazard index was also higher than one, indicating an elevated radiation hazard.

The values of annual gonadal dose equivalent, as a measure of the genetic significance of the annual dose equivalent received by the population, were less than 1 mSv in the investigated areas, except on Mt. Kopaonik, locations Lisina and Pančićev vrh, where this parameter was higher than 1 mSv.

The calculated excess lifetime cancer risk implied that the chance of contracting cancer for residents at the study area of Mts Maljen and Tara was below the global average of $0.29 \times 10^{-3}$ (UNSCEAR, 2000). However, the probability of cancer incidence on Mt. Kopaonik was higher than the world average.

Anthropogenic $^{137}Cs$ was detected in all investigated mountain regions of Serbia.

### Acknowledgements

This paper is a part of the research done within the projects financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia (TR31003 and TR34013, and III43007) (2011–2019).

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Received: November 4, 2019
Accepted: January 29, 2020

# PRIRODNI I PROIZVEDENI RADIONUKLIDI U ZEMLJIŠTU PLANINSKIH REGIONA REPUBLIKE SRBIJE I PARAMETRI RADIJACIONOG RIZIKA

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R e z i m e

U radu su prikazani rezultati gamaspektrometrijskog određivanja sadržaja prirodnih ($^{40}$K, $^{238}$U, $^{226}$Ra i $^{232}$Th) i proizvedenog ($^{137}$Cs) radionuklida u zemljištu sa područja planina Maljen, Tara i Kopaonik. Uzorci zemljišta prikupljeni su u periodu od 2002. do 2015. godine na različitim nadmorskim visinama. Na osnovu sadržaja radionuklida u zemljištu odredili smo parametre radijacionog rizika: radijum ekvivalentnu aktivnost, jačinu doze, godišnju efektivnu dozu spoljašnjeg zračenja, indeks spoljašnjeg hazarda, godišnju gonadnu dozu i faktor rizika pojave kancera na području planinskih regiona Republike Srbije, i potom ih uporedili sa ranije objavljenim rezultatima za pojedine regione Republike Srbije.

**Ključne reči:** zemljište, radionuklidi, gama spektrometrija, parametri radijacionog rizika, planinski region.

Primljeno: 4. novembra 2019.
Odobreno: 29. januara 2020.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 19-35

https://doi.org/10.2298/JAS2001019S
UDC: 633.34:631.8(55)
Original scientific paper

# EVALUATION OF INTEGRATED NITROGEN AND PHOSPHOROUS MANAGEMENT USING THE TT BIPLOT METHOD IN SOYBEAN

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**Abstract:** To investigate the effects of integrated nutrient management on oil, protein, grain yield and some traits of soybean, we conducted a factorial experiment involving 4 bio-fertilizer (no inoculation, inoculation with Barvar-2, inoculation with Biosoy and dual inoculation with Biosoy and Barvar-2) and 3 chemical fertilizer levels (no chemical fertilizer, 66 kg $ha^{-1}$ diammonium phosphates + 50 kg $ha^{-1}$ urea, 132 kg $ha^{-1}$ diammonium phosphates + 100 kg $ha^{-1}$ urea) with 100% chemical fertilizer (200 kg $ha^{-1}$ diammonium phosphates + 150 kg $ha^{-1}$ urea) as control base in a randomized complete block with four replications at the research farm of the University of Mohaghegh Ardabili, Iran. Analysis of variance showed that treatment combinations affected most of the traits (P>0.01). We used the biplot analysis as the treatment × trait (TT) biplot to determine the best treatment combinations and traits. The first two principal components (PC1 and PC2) explained 94 and 96% of the total variant of the standardized data in 2017 and 2018, respectively. Accordingly, application of Biosoy and 150 kg $ha^{-1}$ urea + 200 kg $ha^{-1}$ diammonium phosphate significantly increased stem height at harvest, number of grains per plant, biomass, hundred-grain weight, oil and protein yield, protein percent and grain yield compared to the other treatment combinations. The results showed that there were positive correlations between these traits. Also, non-inoculated plants and no chemical fertilizer treatments significantly increased oil percent. The results indicate that higher-yielding treatment combinations had lower oil percent. The biplot was used for ranking of treatment combinations based on a single trait. These study results suggest that bio-fertilizers had a positive influence on soybean and that they could diminish the use of chemical fertilizers. The study reveals that the TT biplot was able to graphically show the interrelationships between traits and support visual comparison of treatments.

**Key words:** Biosoy, nitrogen, soybean, treatment × trait biplot.

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## Introduction

Soybean (*Glycine max* (L.) Merr.) is one of the most important oilseed crops in the globe (Ali, 2010; SoyStats, 2019) since soybean grains are used for the production of oil and protein for humans, feed for livestock and biofuel for cars. Global production of soybean is expected to be increased to 371.3 million tons until 2030 (Masuda and Goldsmith, 2009). Approximately 76,000 hectares of the soil is under soybean cultivation in Iran with an average yield of 2.44 tons per hectare (FAOSTAT**,** 2013). There is an important scope to increase the area under soybean and grain yield of soybean in Iran (Shahraeen et al., 2005). Among the crucial nutrients, macronutrients such as nitrogen and phosphorus play a crucial role in improving crop growth and yield. Soybean nitrogen demands are met by biological N fixation and soil nitrogen (Milić et al., 2002; McCoy et al., 2018). Nitrogen is the most important element that crops need in the supreme amount and often restricts crop growth and development (Zhao and Shen, 2018) as well as crop yield. Nitrogen affects a lot of physiological processes in higher plants (Cechin and Fumis, 2004). Phosphorus (P) is also another important element for plants. Tsvetkova and Georgiev (2003) reported that P deficiency decreased soybean dry mass and nodule weight. Dry bean grain yield and yield components were significantly increased with P fertilization and associations of grain yield with shoot dry weight and pods per plant were significantly positive (Fageria et al., 2010).

Generally, nitrogen and phosphorus fertilizers were applied to replace soil N and P with the high price and ecological risk. Because of avoidance of environmental problems, people health, and further crop production to cover the growing demand of the global population, combined nutrient management using biological and mineral fertilizers is a proper method to meet crop needs. An ecological way to increase soil fertility and plant productivity might be the use of biofertilizers such as N2-fixing bacteria and phosphate solubilizing bacteria (Sessitsch et al., 2002). Biofertilizers are needed for sustainable farming systems (Schütz et al., 2018). Because of an increase in N and P uptake, nitrogen-fixing and phosphorus solubilizing bacteria are of importance for crops (Zahir et al., 2004; Zaidi and Mohammad, 2006). Therefore, application of these microbes as environmentally friendly bio-fertilizers can reduce the use of expensive nitrogen and phosphorous fertilizers which cause many environmental problems (Serpil, 2012). Also, phosphorus bio-fertilizers produce plant growth-promoting substances that increase P uptake, the efficiency of nitrogen fixation and availability of some microelements to plants (Kucey et al., 1989). Seed inoculation with *Bradyrhizobium* in soils with low N content without N fertilizer application increased biological nitrogen fixation (Smith, 1992). Co-inoculation of soybean and alfalfa by *Pseudomonas* strains and *Rhizobia* produced more nodules and nodule dry weight (Rosas et al., 2006).

The experimental dataset must be analyzed and interpreted effectively. Diverse methods typically cause a similar outcome for a given dataset (Sabaghnia, 2012). The main effect of genotype and genotype by environment (GGE) biplot graphical tool was developed by Yan et al. (2000) for the graphical analysis of multi-environment trials.

Influences of genotypes, environments or testers are shown by the biplot. The GGE effects of multi-environment trials are exhibited by the GGE biplot. It is constructed by plotting the first two principal components (PCs) which are commonly referred to as models that decompose the environment-centered data. (Yan et al., 2007). However, it can also be equally used for all types of two-way data that assume a two-way structure (Yan and Kang, 2003). The treatment combinations can be generalized as rows and the multiple traits, for example, morphologic and physiologic properties as columns. Yan and Rajcan (2002) used a genotype × trait (GT) biplot, which is an application of the GGE biplot technique to investigate the genotype by trait data and is an excellent tool for visualizing the genotype by trait data. The TT biplot was an excellent tool for visualizing treatment combinations by trait data.

The aim of the study was to examine the possibility of reducing the use of N and P fertilizers by using bio-fertilizers by the TT-biplot technique.

## Materials and Methods

### Field experiments

We conducted the experiment in a clay loam soil during 2017 and 2018 growing seasons. The previous crop was wheat. After harvesting wheat, the soil was plowed to a depth of 20 cm, and disked. The soybean seeds were sown manually on June 8, 2017 and June 15, 2018, in both sides of ridges of 50 cm apart, at a density of 50 seeds $m^2$. Each plot consisted of five 4-m long rows, with 50 cm between rows. Weeds were controlled regularly by hand. The farm was irrigated on the basis of the conventional crop system. We arranged a factorial set of treatments on the base of a randomized complete block design with four replications. The biological fertilizer consisted of no-inoculation, inoculation with Barvar-2, inoculation with Biosoy and dual inoculation with Biosoy and Barvar-2. Different levels of the chemical fertilizer were applied: 0%, 33% (66 kg $ha^{-1}$ diammonium phosphate + 50 kg $ha^{-1}$ urea), 66% (132 kg $ha^{-1}$ diammonium phosphate + 100 kg $ha^{-1}$ urea) and 100% (200 kg $ha^{-1}$ diammonium phosphate + 150 kg $ha^{-1}$ urea) of chemical fertilizers. Combination of all 4 bio-fertilizer levels and 3 chemical fertilizer levels including 0%, 33% and 66% was arranged in a factorial experiment. The one-hundred chemical fertilizer level was used as control. Biosoy bio-fertilizer including effective *Bradyrhizobium japonicum* populations was purchased from the Mehr Asia Biotechnology Company and Barvar-2 bio-fertilizer, including two phosphate solubilizing bacteria *Pseudomonas putida s-P13* and *Pantoea agglomerans*, was provided from Green Biotech Co. The population of bacteria in both bio-fertilizers was $10^8$ per gram.

Soybean seeds (cv. Williams) were separated into four samples, and one sample was control (no inoculation). The other samples were inoculated with Biosoy, Barvar-2 and Biosoy + Barvar-2 according to the instructions on their packages, respectively. Chemical fertilizers were applied in bands on one side of rows after planting. Ten plants from central rows were randomly harvested to measure yield and yield components.

### Data analysis

In biplot graphs, the different biological fertilizer levels were no inoculation (B0), inoculation with Barvar-2 (B1), inoculation with Biosoy (B2) and dual inoculation with Biosoy and Barvar-2 (B3). Different levels of chemical fertilizers were no chemical fertilizer (F0), 66 kg $ha^{-1}$ diammonium phosphates + 50 kg $ha^{-1}$ urea (F1), 132 kg $ha^{-1}$ diammonium phosphates + 100 kg $ha^{-1}$ urea (F2), and 200 kg $ha^{-1}$ diammonium phosphates + 150 kg $ha^{-1}$ urea as control (F3). All of the biplots were created by the GGE biplot software (Yan, 2001).

## Results and Discussion

### Analysis of variance

Combined analysis of variance over two years exposed significant differences (P>0.01) among treatment combinations for all the traits but the grain number per pod (Table 1). The effect of the year on the studied traits was insignificant. Except for grain yield, treatment combinations × year interactions were insignificant for all other traits. The results indicated that increasing application of chemical fertilizers had a noteworthy influence on all traits and except for oil percentage, increased the value of all other traits. Combined inoculation with Biosoy and Barvar-2 was more effective than inoculation with a single microorganism. Seeds inoculated with Biosoy and Barvar-2 + Biosoy had greater values than non-inoculated and inoculated seeds by Barvar-2 in most traits, but had lower values for oil percentage. It is notable that, in most traits such as grain and oil yields, application of Biosoy and Barvar-2 + Biosoy inoculums without any use of chemical fertilizers achieved higher values than 100% of chemical fertilizers. Usually, in inoculated plants with Biosoy and Barvar-2 + Biosoy, application of 33% of chemical fertilizers improved most of the traits but higher doses of chemical fertilizers did not improve the traits.

Table 1. Mean squares of measured traits for combined analysis of variance of 13 treatment combinations across 2 years.

| S.O.V. | df | PH | BM | NP | NGP | NG | HGW |
|---|---|---|---|---|---|---|---|
| Year (Y) | 1 | 85.02 | 13.08 | 24.58 | 0.59 | 81.7 | 142.7 |
| Replication/Y | 4 | 42.25 | 1.80 | 6.01 | 0.06 | 55.4 | 82.7 |
| Treatment combination (T) | 12 | 923.96** | 52.94** | 72.14** | 0.08 | 407.3** | 1412.4** |
| Control | 1 | 22.24 | 1.30 | 8.36 | 0.04 | 11.5 | 189.0 |
| Biological fertilizer (A) | 3 | 3247.73** | 183.10** | 202.43** | 0.19* | 1292.5** | 5323.5** |
| Chemical fertilizer (B) | 2 | 325.53* | 22.75* | 68.35** | 0.04 | 268.5* | 23.0* |
| A× B | 6 | 111.84** | 6.54** | 18.90** | 0.04 | 76.9** | 123.8 |
| T × Y | 12 | 2.41 | 0.92 | 0.67 | 0.02 | 5.1 | 35.2 |
| Control × Y | 1 | 0.00 | 2.98* | 0.15 | 0.02 | 10.3 | 45.8 |
| A × Y | 3 | 2.49 | 0.76 | 0.92 | 0.02 | 2.1 | 22.9 |
| B × Y | 2 | 3.68 | 0.59 | 0.03 | 0.03 | 9.5 | 29.0 |
| A × B × Y | 6 | 2.34 | 0.77 | 0.84 | 0.01 | 4.3 | 41.6 |
| Experimental Error | 48 | 1.97 | 0.64 | 0.46 | 0.01 | 3.5 | 30.2 |

**, * Significance at 0.01 and 0.05 levels, respectively. PH: plant height; BM: biomass; NP: number of pod; NGP: number of grain per pod; NG: number of grain per plant; HGW: hundred-grain weight; GY: grain yield; P%: protein percent; O%: oil percent; PY: protein yield; OY: oil yield; CH: chlorophyll index.

Table 1. Continued.

| S.O.V | GY | P% | O% | PY | OY | CH |
|---|---|---|---|---|---|---|
| Year (Y) | 1714.8 | 1.21 | 1.17 | 239.4 | 96.3 | 95.5 |
| Replication/Y | 1102.1 | 0.11 | 0.18 | 178.1 | 31.6 | 40.4 |
| Treatment combination (T) | 23947.7** | 30.30** | 5.2** | 5589.5** | 501.9** | 230.2** |
| Control | 2510.0 | 2.81 | 0.92 | 721.2 | 30.4 | 39.5 |
| Biological fertilizer (A) | 84886.3** | 115.21** | 19.32** | 20254.5** | 1698.6** | 860.1** |
| Chemical fertilizer (B) | 5759.1** | 3.06 | 0.58** | 1037.4* | 177.8* | 38.0 |
| A× B | 3114.2** | 1.50* | 0.34* | 585.7** | 90.1** | 11.0* |
| T × Y | 167.4* | 0.54 | 0.1 | 29.9 | 6.3 | 7.8 |
| Control × Y | 682.3** | 0.14 | 0.17 | 104.3** | 28.6** | 45.2 |
| A × Y | 78.8 | 1.34** | 0.23* | 20.2 | 1.9 | 8.9 |
| B × Y | 55.6 | 0.53* | 0.00 | 14.6 | 2.0 | 3.8 |
| A × B × Y | 163.1 | 0.21 | 0.05 | 27.3 | 6.1 | 2.4 |
| Experimental Error | 74.9 | 0.15 | 0.06 | 12.6 | 3.7 | 52.6 |

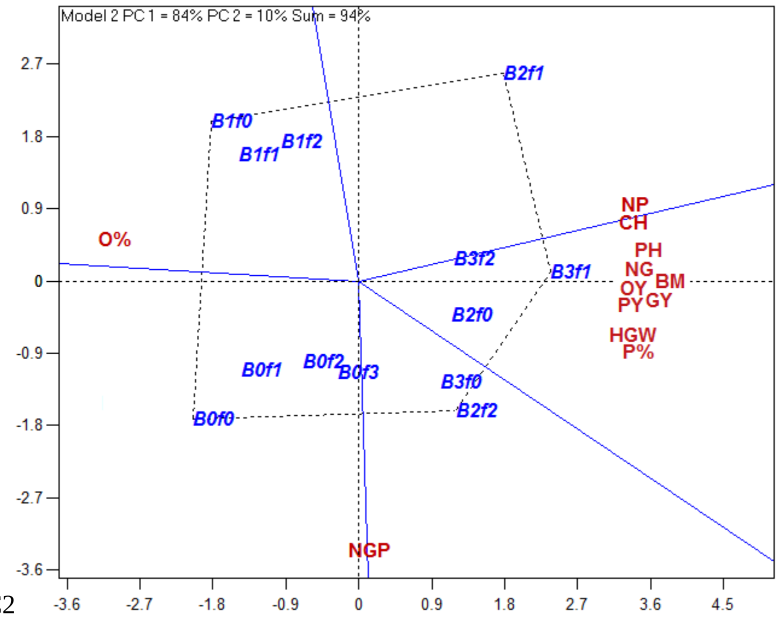
**, * Significance at 0.01 and 0.05 levels, respectively. PH: plant height; BM: biomass; NP: number of pod; NGP: number of grain per pod; NG: number of grain per plant; HGW: hundred-grain weight; GY: grain yield; P%: protein percent; O%: oil percent; PY: protein yield; OY: oil yield; CH: chlorophyll index.

Biplot analysis

The treatment combination evaluation based on multiple characters is a vital feature of biplot analysis. An ideal treatment combination must meet numerous requirements. For example, not only yield but also end-use quality must be acceptable in a high-yielding treatment combination. Also, yield and quality can be divided into many components. For the target trait of some components, it is essential to define the most useful components to avoid unintended selection. Figures 1a and 1b show the records of 13 treatment combinations with 12 measured traits. The polygon view is based on PC axes (PC1 and PC2) in which the traits are the tester and the 13 treatment combinations are entries. The first two biplot axes in Figure 1 explained 94 and 96% of the entire deviation of the standardized data in 2017 and 2018, respectively.

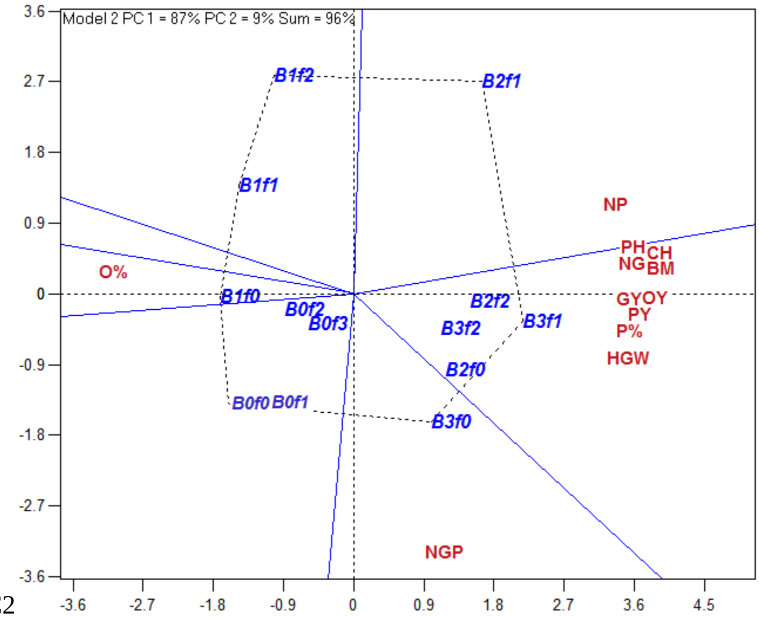
There are five and seven vertex treatments in Figure 1a (The first year) and Figure 1b (The second year), four of them (*B3f1*, *B1f0*, *B2f1* and *B0f0*) were good for several traits, but the others were not good or were unfavorable. The *B3f1* was the best in terms of plant height at harvest (PH), number of grains per plant (NG), biomass (BM), hundred-grain weight (SW), protein percent (P%), protein content (PY), oil percent (OY), chlorophyll index (CH), and grain yield (GY), and therefore, it seems that dual inoculation with Biosoy and Barvar-2 × 66 kg $ha^{-1}$ diammonium phosphate + 50 kg $ha^{-1}$ urea could increase the value of many characteristics of soybean. In contrast, the *B1f0* treatment combination (Barvar-2 + no chemical fertilizer) was the best for oil percent (0 %), and therefore, it seems that this trait is sensitive to the chemical fertilizer and Biosoy (Figures 1a and 1b). The polygon view of biplot shows that *B0f0* (no inoculation + no chemical fertilizer) was the best in terms of grain number per pod (NGP). The data indicated that the grain number per pod was not correlated with other traits (Figure 1). These results are in agreement with the Pearson correlation coefficients in Table 2. Dual inoculation with Biosoy + Barvar-2 significantly achieved the uppermost number of grains per pod with 2.51 and 2.45 grains, respectively. Our outcome is in contrast with Argaw (2012) who showed that the use of bio-fertilizers decreased the use of the chemical fertilizers. Each year, the traits fell into the same groups and the treatment combination × trait biplots were similar in the two years.

In Figures 1c and 1d, the vertex treatment combinations are those that had the lowermost values for one or more traits. Thus, *B3f1* had the lowest value for oil percent over the two years. This pattern was different for other traits in 2017 and 2018, nonetheless, *B0f0*, *B1f0* and *B1f1* had the lowest values for PH, NG, BM, GY, PY, OY, CH, P% and HGW.




PC2

a PC1




PC2

b PC1

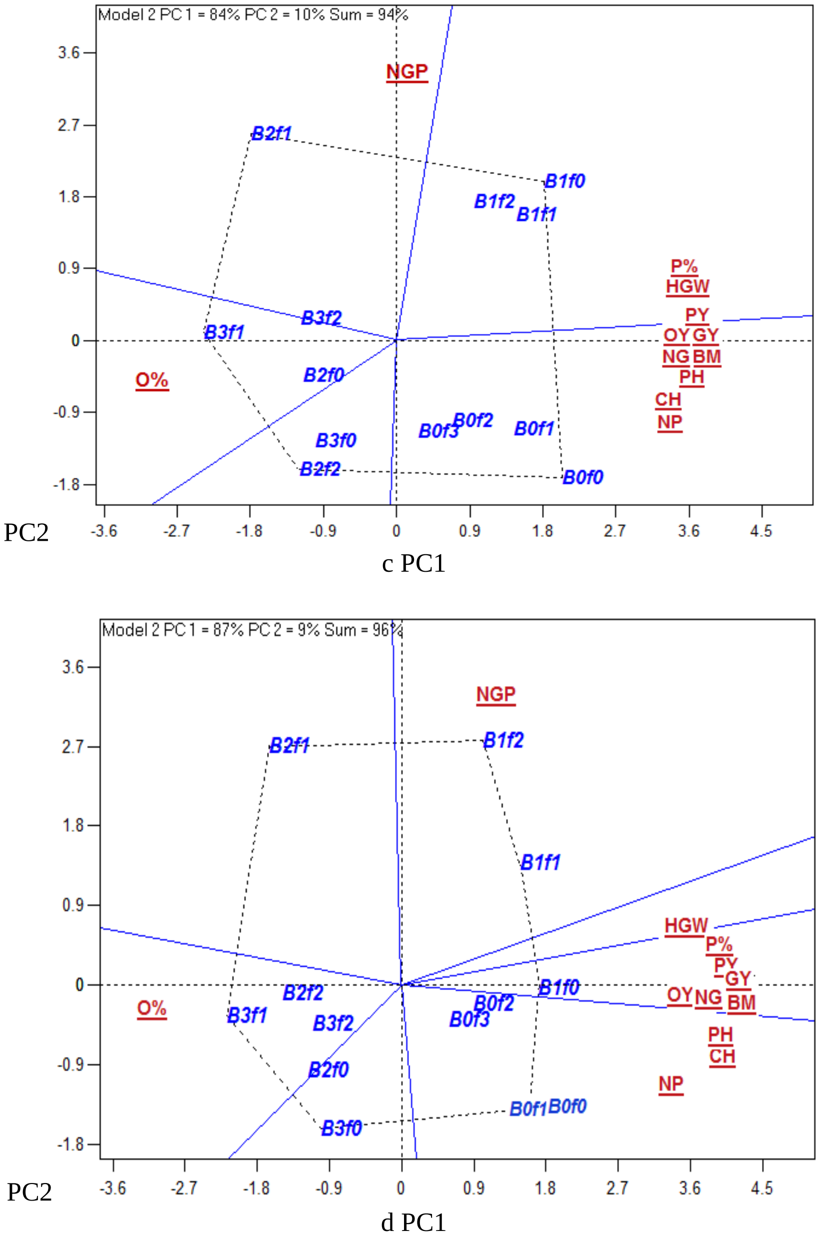
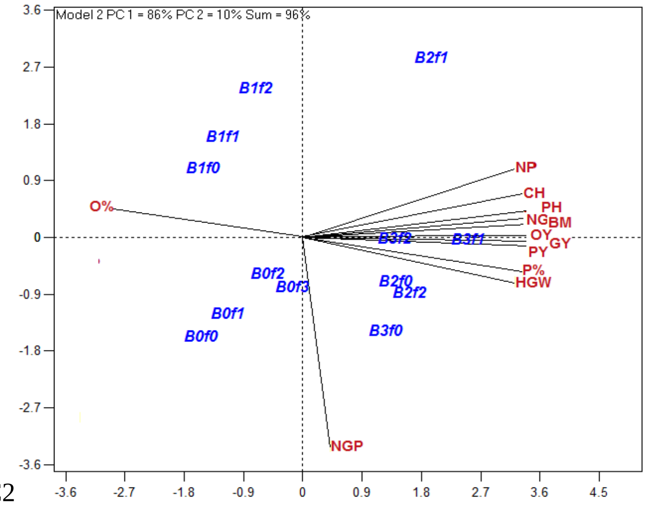



Figure 1. Treatment combinations by trait biplot for (a) the first year and (b) the second year, showing which treatment combination had the highest values for which traits; (c) the first year and (d) the second year, showing which treatment combination had the lowest values for which traits.

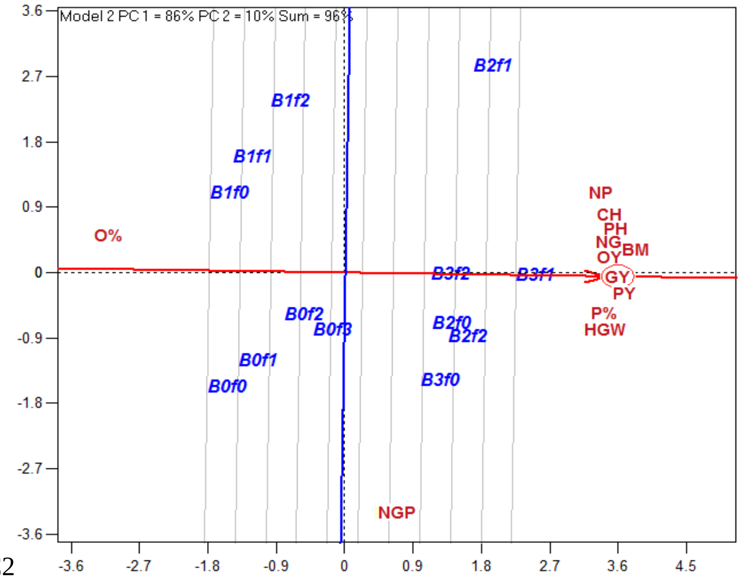
The interrelationships among all the measured traits are shown by the vector view of the TT biplot (Figure 2a). Yan et al. (2007) show that the cosine of the angle between the vectors of any two traits approximates the correlation coefficient between them. Figure 2 shows that PH, NG, BM, GY, PY, P%, HGW, OY and CH traits were extremely and positively associated. These traits were also negatively associated with oil percent and the increase of these traits caused the decrease of oil percent. Vollmann et al. (2011) reported that nodulating of soybean by B. *japonicum* increased leaf dimensions, time to maturity, stem height, numbers of pods and weight of 1000 grains. Grain protein content was severely amplified in soybeans with nodules in comparison with non-nodulated lines, whereas, on the other hand, non-nodulated plants had greater oil percent than nodulated plants. Zerihun et al. (2015) have noted that when soybeans planted in soils with neutral pH, rhizobium inoculation and application of 50 kg $ha^{-1}$ of diammonium phosphate treatment combination are recommended. Piccinin et al. (2011) also stated that the application of a half dose of N for plants inoculated with *Azospirillum brasilense* increased the performance and yield of wheat.

Treatment combination evaluation based on individual traits

The GGE biplot methodology ranks treatment combinations based on a single trait. Based on seed yield (Figure 2b), *B3f1* is the best treatment combination, followed by *B2f1*, *B2f2*, *B3f2*, *B2f0* and *B3f0*. All these treatment combinations had an above-average yield. The other treatment combination had a below-average yield. For plants from non-inoculated seeds, an increase in the chemical fertilizer application enhanced grain yield. When seeds were inoculated by Barvar-2, bio-fertilizer grain yield was like that of non-inoculated seeds (Figure 2b).

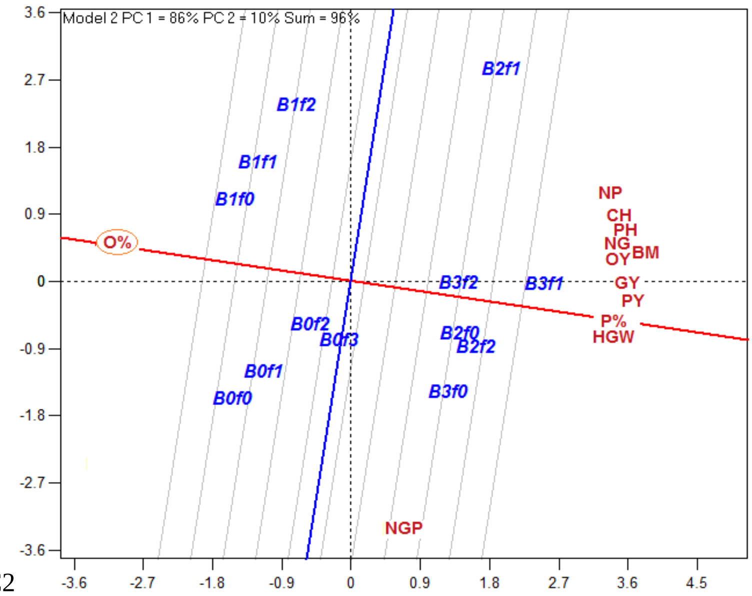



a PC1




PC2

b PC1




PC2

c PC1

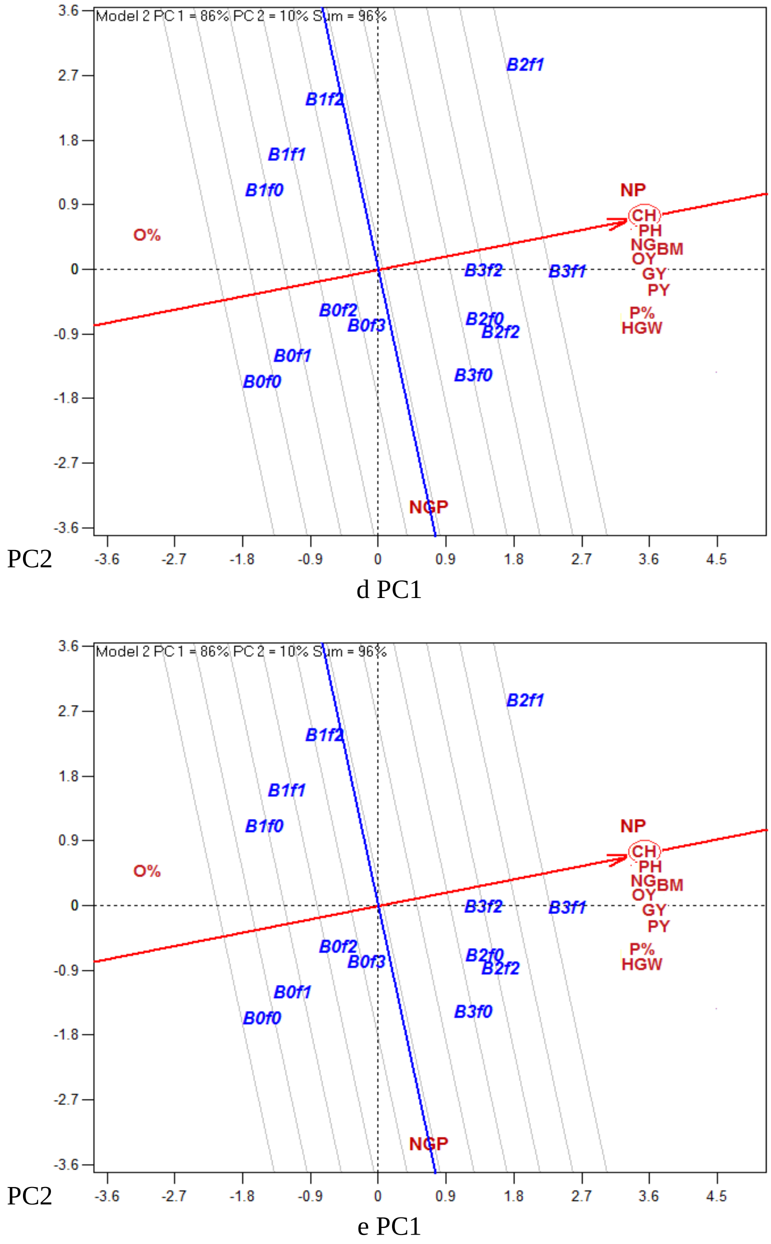



Figure 2. Biplots (a) The vector view of treatment combination by trait biplot for the mean of two years, (b) comparing the performance of grain yield, (c) protein percent, (d) oil percent and (e) chlorophyll index at different treatment combinations.

Also, at all levels of chemical fertilizers, inoculated plants with Barvar-2 were not superior to non-inoculated ones (data not shown). Seeds inoculated by Biosoy and Biosoy + Barvar-2 produced the highest grain yield at the 33% chemical fertilizer application, and a further rise in fertilizer led to a reduction in grain yield, so that the lowest grain yield was achieved at 200 kg $ha^{-1}$ diammonium phosphate + 150 kg $ha^{-1}$ urea (100%) (Table 2). Some researchers like Argaw (2012), Wasule et al. (2007) and Son et al. (2006) obviously discovered that dual inoculation of seeds by *B. japonicum* and phosphate solubilizing bacteria expressively had higher growth and yield components than the sole application of both types of bacteria. Similar results stated by Qureshi et al. (2009) showed that seed inoculation with *M. ciceri* or *A. chroococcum* significantly enhanced plant biomass and grain yield, but the response was more pronounced with co-inoculation. Tyagi et al. (2003) found that among the various bio-fertilizer treatments, co-inoculation of *Rhizobium* + PSB produced the highest grain yield even greater than *Rhizobium* or PSB treatment. An increase in nodulation, grain yield, biological yield and N fixation due to co-inoculation with *B. japonicum* and PSB was reported by Son et al. (2006) and Abd-alla and Omar (2001). The same result was stated by Wang et al. (2019).

Based on protein content (Figure 2c), the best treatment combinations were *B3f1* and *B2f2*, followed by B2f1, *B2f0*, *B3f0*, *B3f2,* etc. For plants from non-inoculated seeds, an increase in chemical fertilizer application enhanced protein content. Ham et al. (1975), Mamatha et al. (2018) and Tahir et al. (2009) observed that protein content was significantly enlarged by nitrogen application. An increase in seed protein due to phosphorus fertilizer application on soybean (Gaydou and Arrivets, 1983) and beans (Zafar et al. 2011) was reported. Seguin and Zheng (2006) observed some increase in protein percent by phosphorus fertilizer. Grain protein content of the inoculated plants with Biosoy (mean = 113.5 $g.m^2$) and Biosoy + Barvar-2 (mean = 119.3 $g.m^2$) was significantly different from the non-inoculated (mean = 65.1 $g.m^2$) and inoculated plants with Barvar-2 (mean = 55.8 $g.m^2$) (data not shown). It seems that inoculated plants with N-fixing bacteria due to higher content of nitrogen produced greater protein content than non-inoculated ones.

However, at all chemical fertilizer levels, there were no differences between inoculated plants with Barvar-2 and non-inoculated plants in terms of seed protein content. Also, the best treatment combination for oil percent was *B1f0*, followed by *B1f1*, *B0f0*, *B1f2*, *B0f1*, *B0f2*, *B0f3*, etc. (Figure 2d). The results indicated that the high-yielding treatment combinations are the poorest in oil percent. The largest grain oil percent was related to plants inoculated with Barvar-2. A statistically significant difference in seed oil percent between the inoculated plant with Biosoy (mean = 16.4%) and Biosoy + Barvar-2 (mean = 16.2%) with non-inoculated (mean = 18.0%) and inoculated plants with Barvar-2 (mean = 18.1%) was found (data not shown), which is probably because of the adverse effect of nitrogen on the oil synthesis in soybean. No significant difference between different chemical fertilizer levels was found in seed oil percent.

Table 2. Pearson's correlation coefficients among studied traits at different treatment combinations.

| Traits | PH | BM | NP | NGP | NG | HGW | GY | P% | O% | PY | OY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BM | .873** (Year 1) | | | | | | | | | | |
| | .880** (Year 2) | | | | | | | | | | |
| NP | .852** | .854** | | | | | | | | | |
| | .844** | .856** | | | | | | | | | |
| NGP | -0.091 | -0.023 | -0.25 | | | | | | | | |
| | 0.12 | 0.212 | -0.027 | | | | | | | | |
| NG | .868** | .880** | .869** | -0.008 | | | | | | | |
| | .855** | .886** | .865** | 0.232 | | | | | | | |
| HGW | .737** | .736** | .713** | 0.051 | .661** | | | | | | |
| | .803** | .801** | .760** | 0.379 | .751** | | | | | | |
| GY | .866** | .885** | .826** | 0.002 | .861** | .805** | | | | | |
| | .866** | .885** | .820** | 0.297 | .879** | .838** | | | | | |
| P% | .813** | .781** | .792** | 0.142 | .761** | .824** | .827** | | | | |
| | .840** | .828** | .807** | 0.293 | .769** | .874** | .832** | | | | |
| O% | -.795** | -.753** | -.761** | -0.041 | -.709** | -.837** | -.801** | -.869** | | | |
| | -.830** | -.810** | -.791** | -0.27 | -.746** | -.844** | -.805** | -.886** | | | |
| PY | .866** | .879** | .816** | 0.015 | .854** | .816** | .899** | .842** | -.818** | | |
| | .868** | .884** | .809** | 0.303 | .871** | .851** | .899** | .846** | -.821** | | |
| OY | .861** | .889** | .839** | 0.001 | .872** | .773** | .895** | .798** | -.757** | .890** | |
| | .855** | .879** | .827** | 0.289 | .884** | .817** | .897** | .805** | -.770** | .893** | |
| CH | .861** | .811** | .813** | -0.208 | .804** | .660** | .790** | .731** | -.751** | .789** | .779** |
| | .855** | .870** | .820** | 0.145 | .838** | .813** | .862** | .828** | -.822** | .866** | .848** |

**, Correlation is significant at the 0.01 level.

Generally, increasing the chemical fertilizer application enhanced the chlorophyll index for non-inoculated seeds (Figure 2e). This enhancement was insignificant among 0%, 33%, and 66% fertilizer applications, but 100% chemical fertilizer significantly had higher chlorophyll index than 0%. The inoculation of seeds with Biosoy resulted in the highest chlorophyll index when plants received only 33% chemical fertilizer (data not shown). Based on the chlorophyll index (Figure 2e), the best treatment combinations were *B3f1* and *B2f1*, followed by *B2f2*, *B3f2*, *B2f0*, *B3f0*, etc. Dual inoculation of Biosoy and Barvar-2 increased chlorophyll indices at low rates of the chemical fertilizer, but at a high rate (100%), it was significantly reduced. A single inoculation of Biosoy and dual inoculation with Biosoy and Barvar-2 produced a higher chlorophyll level than no inoculation and Barvar-2 bio-fertilizer at 0, 33, and 66% chemical fertilizer because of a reduction of bio-fertilizer effectiveness. A similar result was reported by Zarei et al. (2011) for soybean.

## Conclusion

The current investigation designed to examine the influence of bio-fertilizer treatments on the performance of soybean under different doses of chemical fertilizer. Generally, the highest seed yield was recorded for dual inoculation of Biosoy and Barvar-2 and the application of 33% chemical fertilizer. This could be due to higher nitrogen and phosphorus availability for inoculated plants dually by Biosoy and Barvar-2. However, these bio-fertilizers cannot provide all N and P nutrients needed for plants. When seeds were inoculated with Biosoy and Biosoy + Barvar-2, plants showed the highest performance at 33 percent of the recommended dose of fertilizers. Therefore, nitrogen-fixing bacteria had the potential to reduce chemical fertilizers and increase yield.

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Received: May 26, 2019
Accepted: December 6, 2019

# EVALUACIJA INTEGRISANOG UPRAVLJANJA AZOTOM I FOSFOROM KORIŠĆENJEM METODE DVOSMERNE TO (TREATMANI X OSOBINE) BIPLOT ANALIZE KOD SOJE

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## R e z i m e

Kako bismo ispitali uticaje integrisanog upravljanja hranljivim materijama na sadržaj ulja, proteina, prinos zrna i još neke osobine soje, sproveli smo faktorijalni eksperiment uključujući 4 bio-đubriva (bez inokulacije, inokulacija biođubrivom Barvar-2, inokulacija biođubrivom Biosoy, dvojna inokulacija biođubrivima Biosoy i Barvar-2) i 3 hemijska đubriva (bez hemijskih đubriva, 66 kg $ha^{-1}$ diamonijum fosfata + 50 kg $ha^{-1}$ uree, 132 kg $ha^{-1}$ diamonijum fosfata + 100 kg $ha^{-1}$ uree) sa 100% hemijskim đubrivom (200 kg $ha^{-1}$ diamonijum fosfata + 150 kg $ha^{-1}$ uree) kao kontrolne varijante u potpuno slučajnom blok sistemu sa četiri ponavljanja na istraživačkom imanju Univerziteta Mohaghegh Ardabili, Iran. Analizom varijanse se pokazalo da kombinacije tretmana utiču na većinu osobina (P>0,01). Korišćene su TO (tretmani x osobine) biplot analize kako bismo odredili najbolje kombinacije tretmana i osobina. Prve dve glavne komponente (GK1 i GK2) objasnile su 94 i 96% ukupne varijante standardizovanih podataka u 2017. odnosno 2018. godini. Shodno tome, primena biođubriva Biosoy i 150 kg $ha^{-1}$ uree + 200 kg $ha^{-1}$ diamonijum fosfata značajno je povećala visinu stabljike prilikom žetve, broj zrna po biljci, biomasu, masu 100 zrna, prinos ulja i proteina, procenat proteina i prinos zrna u poređenju sa drugim kombinacijama tretmana. Rezultati su pokazali da postoje pozitivne korelacije između ovih osobina. Takođe, neinokulisane biljke i tretmani bez hemijskog đubriva značajno su povećali procenat ulja. Rezultati su ukazali da su visokoprinosne kombinacije tretmana imale niži procenat ulja. TO biplot analiza je korišćena za rangiranje kombinacija tretmana na osnovu pojedinačne osobine. Rezultatima ovog istraživanja sugeriše se da su biođubriva imala pozitivan uticaj na soju i da bi ona mogla da smanje upotrebu hemijskih đubriva. Istraživanjem se, takođe otkriva da su se TO biplot analizom mogle grafički pokazati međusobne veze između osobina i podržati vizuelno poređenje tretmana.

**Ključne reči:** Biosoy, azot, soja, TO (tretmani x osobine), biplot analiza.

Primljeno: 26. maja 2019.
Odobreno: 6. decembra 2019.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 37-46

https://doi.org/10.2298/JAS2001037H
UDC: 633.17:631.559(624)
Original scientific paper

# EFFECT OF SOWING TECHNIQUES ON YIELD AND RAINFALL PRODUCTIVITY OF PEARL MILLET IN GARDUD SOIL OF NORTH KORDOFAN STATE

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**Abstract:** Pearl millet is grown in environments that are drought-prone areas. The climate change is expected to increase vulnerability in all agro-ecological zones through rising temperature and more erratic rainfall, which will have drastic consequences on food security. Pearl millet is the cereal crop that has a great potential for ensuring food security and income generation in marginal areas because of its suitability to the extreme limits of agriculture. This study was carried out at the Jebel Kordofan experimental site, Sheikan province in North Kordofan state during 2010–2012 seasons to evaluate the effect of different sowing techniques on yield and rainfall productivity of local and improved millet cultivars. Treatments were a combination of four sowing techniques and two cultivars of pearl millet. The sowing techniques were: dry sowing, wet sowing, deep dibbling (10-cm depth) and priming with micro-dozing fertilizer. The two cultivars were Ashana (improved) and Dembi (local). These treatments were arranged in a split-plot design, the main plot for cultivars and subplot for sowing methods in four replications. The parameters studied were days to 50% flowering, plant height (cm), grain yield (kg/ha) and rainfall productivity (kg/ha/mm). The cultivars showed highly significant differences in the number of days to 50% flowering, plant height (cm), grain yield (kg/ha) and rainfall productivity (kg/ha/mm). The dry sowing technique significantly ($P \leq 0.05$) produced the tallest plant (149cm), higher water use efficiency (5.10 kg/ha/mm) and the highest grain yield (1637 kg/ha). It can be concluded that the seedbed prepared with a chisel plough and sown on dry soil produced the highest grain yield.

**Key words:** sowing techniques, millet cultivars, rainfall use efficiency, yield.

## Introduction

Pearl millet (*Pennisetum glaucum (L.) R.Br*) is one of the two major crops grown to feed people living in the semi-arid, low-input dry land agricultural

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regions of Africa and Southeast Asia. It is a potential alternative grain crop for areas of the Great Plains with sandy soil, low rainfall, and a short growing season since dwarf hybrids with a good yield potential have been developed (Maman et al., 1999; FAO and ICRISAT, 1996). In Sudan, pearl millet area is about 1–2 million ha, with average grain yield of 0.2–0.4 t/ha and a total annual production of 0.2–0.6 million tons. About 95% of this area is found in western Sudan state, mainly in the sandy areas (Goz) which occupy the northern parts of these states. The yield is generally very low with the average of 240hg/ha (Abuelgasim, 2001).

Due to increasing water scarcity, particularly for agriculture, and high competition for water for urban and industrial uses, agriculture is expected to be increasingly dependent on rainfall as the cheapest source of water and maximizing the efficiency of its use to produce crop will be vital. Rainwater productivity can be increased further by timely farm operations such as timely planting and weeding. The adoption of agronomic procedures such as minimum tillage, appropriate fertilizer use, timely weeding, disease and insect control, timely planting, in conjunction with new cultivars has the potential to increase the yield and rainfall use efficiency of dryland crops (Turner, 2004). Water use efficiency is influenced by weather conditions that affect plant growth and development and ultimately, yield (Gracia et al., 2009; Hassan, 2013).

Pearl millet is adapted to the poor soil and low rainfall conditions, in addition to its capability of rapid and vigorous growth under favourable conditions. The objective of this study is to identify the effect of different sowing techniques on rainfall use efficiency and yield of local and improved pearl millet cultivars.

## Materials and Methods

Site. This work was conducted for three seasons (2010, 2011 and 2012 and) at El-Obeid Research Station, the demonstration farm, Jebel Kordofan. The total annual rainfall received was 235 mm, 211 mm and 288 mm, respectively for three seasons (Table 1). The soil is sandy clay loam soil locally known as gardud (62% sand, 20% clay and 18% silt). It is characterized by surface compaction and a bulk density that increases substantially at a 15-cm depth from the surface (Omer, 1990). The mean soil moisture content at the beginning of each of the three seasons was 7%, 5% and 9%; and 6%, 6% and 8% at the end of each season, respectively. The soil was ploughed (before sowing) by the chisel plough to improve its physical properties.

Treatments were a combination of two pearl millet cultivars and four sowing techniques.

Cultivars. Two pearl millet cultivars were used in this study. First, Ashana known as Okashana-2, an open-pollinated variety introduced from the SADC region of Southern Africa and released in Sudan in 1996 as early maturing (75 days), high yielding and resistant to downy mildew disease caused by (*Sclerospora graminicola* (Sacc.) J. Schröt.) (Mahietal, 1995). Second, Dembi cultivar is the most popular and widely grown local variety in Kordofan. It has a light brown to yellowish-brown seed color and is comparatively late in maturity (around 120 days) with medium or tall plant height.

Table 1. Rainfall amounts and distribution for seasons of 2010, 2011 and 2012 at Jebel Kordofan.

| Month | Season of 2010 | | Season of 2011 | | Season of 2012 | |
|---|---|---|---|---|---|---|
| | Rainfall (mm)/month | Rainy days/month | Rainfall (mm)/month | Rainy days/month | Rainfall (mm)/month | Rainy days/month |
| June | 18.0 | 1 | - | - | - | - |
| July | 80.5 | 6 | 55.5 | 4 | 43.0 | 3 |
| August | 96.5 | 7 | 88.0 | 7 | 160.0 | 5 |
| September | 36.0 | 2 | 50.5 | 3 | 58.0 | 4 |
| October | 4.0 | 1 | 17.0 | 2 | 27.0 | 2 |
| Total | 235.0 | 17 | 211.0 | 16 | 288.0 | 14 |

Source: El-Obied research station.

Sowing techniques. Dry seeding: seeds were sown on dry soil to catch early rainfall showers as a method of planting farmers usually practice during April–May.

- Wet seeding: seeds were sown in wet soil after effective rainfall.
- Dibbling: seeds were sown at 10-cm depth.
- Priming and micro-dozing fertilizer: seeds were soaked in water for 8hrs and sown together with 0.3g/hole of NPK (17-17-17) equivalent to 8 kg/ha of fertilizer (Osman et al., 2010).

Design and replications. A split-plot design was used – main plots were cultivars and subplots were the sowing methods with four replications. Plot size was 5m width x 5m length area and net area of 3m x 5m.

Cultural practices. Land was prepared with a tractor-mounted chisel. Seeds were treated with Apron star at a rate of 3gm/kg (for all seed treatments). Sowing date: sowing was done manually as described below in Table 2.

The spacing used for Ashana cultivar was (75cm x 50cm, 6 rows) and Dembi (100cm x 75cm, 5 rows) (Hassan et al., 2011). The seedlings were thinned to 2–3 plants/hole. Plots were hand-weeded twice during the growing season. Other management practices followed ARC recommendations.

Data collection. Data was collected from the central rows (6 rows for Ashana and 3 rows for Dembi) of each plot, by discarding the marginal rows. The numbers of days to 50% flowering were recorded (days from plant emergence to 50% flowering). Plant height (cm) was measured as the average of 10 plants. Grains/plot were measured and expressed as yield (kg/ha). Rainfall use efficiency was calculated by dividing the total yield by the amount of rainfall received during the season and expressed as kg/ha/mm.

Table 2. Dates of sowing for the four sowing techniques.

| Sowing techniques | 1st season | 2nd season | 3rd season |
|---|---|---|---|
| Dry sowing | 28/6/2010 | 18/7/2011 | 15/7/2012 |
| Wet sowing | 7/7/2010 | 24/7/2011 | 19/7/2012 |
| Deep ripping | 7/7/2010 | 24/7/2011 | 19/7/2012 |
| Priming and micro-dozing | 7/7/2010 | 24/7/2011 | 19/7/2012 |
| Harvesting date | 12/10/2010 | 17/10/2011 | 11/10/2012 |

Statistical analysis. Data for each season in addition to combined data were subjected to statistical analysis by the MSTAT-C statistical package developed by Michigan State University as described by Gomez and Gomez (1984).

## Results and Discussion

The combined analysis of data during 2010–2012 seasons showed highly significant differences for the number of days to 50% flowering, yield, yield attributes and rainfall use efficiency due to seasons. The seasons interacted significantly with methods of sowing on 50% flowering and rainfall use efficiency.

The significant difference due to varieties appeared on mean number of days to 50% flowering (Table 3) where the early maturing cultivar (Ashana) flowered earlier than the late maturing local cultivar (Dembi) under rain-fed conditions. A similar result was reported on different locations of these varieties (Abdalla et al., 2012).

Table 3. The effect of cultivars on the number of days to 50% flowering, plant height (cm), grain yield (kg/ha) and rainfall use efficiency (kg/ha/mm) combined for three seasons at Jebel Kordofan site.

| Cultivars | Number of days to 50% flowering | Plant height (cm) | Grain yield (kg/ha) | Rainfall use efficiency (kg/ha/mm) |
|---|---|---|---|---|
| Ashana | 51 | 138 | 1547 | 5.62 |
| Dembi | 61 | 148 | 1056 | 3.87 |
| SE ± | 0.45*** | 2.8* | 79.3** | 0.23** |
| C.V. (%) | 7.2 | 8.6 | 42.2 | 41.2 |

Methods of sowing showed no significant difference in the number of days to 50% flowering, but interacted significantly with seasons and varieties and revealed that the dry sowing method attained the 50% flowering earlier (43 days) of the cultivar Ashana, in the season with high rainfall (2012) than the latest dibbling methods (70 days) of Dembi, for the same season (Table 5).

Table 4. The effect of methods of sowing on plant height (cm), grain yield (kg/ha) and rainfall use efficiency (kg/ha/mm) combined for three seasons at Jebel Kordofan site.

| Sowing techniques | Plant height (cm) | Grain yield (kg/ha) | Rainfall use efficiency (kg/ha/mm) |
|---|---|---|---|
| Dry sowing | 149 | 1637 | 5.91 |
| Wet sowing | 141 | 1311 | 4.75 |
| Deep dibbling | 141 | 1211 | 4.44 |
| Priming and fertilizer | 143 | 1048 | 3.88 |
| SE ± | 2.2* | 115** | 0.41** |
| C.V. (%) | 8.6 | 42.2 | 41.2 |

The plant height was significantly affected by cultivars and sowing methods. The local cultivar (Dembi) gave the taller plants (148cm) than Ashana (138cm) in this study as the difference in the cultivar genetic composition (Table 3). This finding is similar to Abdalla et al. (2012) and Mohamed et al. (2013) in finding difference heights across the major pearl millet growing region. The planting methods significantly ($P \geq 0.05$) affected plant height (cm). The dry sowing method gave the tallest plants in comparison to the other methods (Table 4), and this could be attributed to the efficient use of rainfall for growth. This is in conformation with the findings of Eastham and Gregory (2000) findings that, in dry seeding, seeds emerge at the onset of rains and thereby gain several days for more growth than sowing after rain. Also, Mohamed et al. (2013) concluded that early sowing produced taller plants of pearl millet.

The varietal difference was highly significant ($P \leq 0.01$) on grain yield. The improved cultivar (Ashana) produced higher grain yield (1547kg/ha) than the local one (Dembi) (1056kg/ha) (Table 3) and also among the study seasons (Table 7). This varietal difference was confirmed by many researchers (Hassan et al., 2011; Abdalla et al., 2012; Mohamed et al., 2013).

The sowing methods play an important role in obtaining higher yield. Grain yield was highly significantly affected by sowing methods in the combined analysis. Higher grain yield was obtained by dry sowing and lower yield from priming and fertilizer (Table 4). The increments in grain yield from the dry sowing method were 24%, 35% and 56% over the wet, dibbling and priming methods, respectively (Figure 1). This might have been associated with the utilization of rainwater in early sowing. This matches the results of Upadhyay et al. (2001) who reported that higher grain yield was obtained from early sowing and considerable reduction in yield with delayed sowing. On the other hand, Shinggu and Gani

(2012) reported that the planting method and the sowing date did not have an effect on grain yield and 100-seed weight.

Table 5. The interaction between cultivars, methods of sowing and seasons on the number of days to 50% flowering (2010–2012 seasons) at Jebel Kordofan site.

| Sowing methods | Ashana | | | Dembi | | | Mean | SE ± |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 | | |
| Dry sowing | 64 | 54 | 43 | 64 | 65 | 53 | 57 | 0.84ns |
| Wet sowing | 55 | 52 | 44 | 55 | 63 | 65 | 56 | |
| Dibbling sowing | 55 | 52 | 44 | 55 | 61 | 70 | 56 | |
| Priming and fertilizer | 55 | 53 | 44 | 55 | 60 | 69 | 56 | |
| Season mean | 57 | 53 | 44 | 57 | 62 | 64 | | |
| Mean (cultivars) | | 51 | | | 61 | | | |
| SE ± | 0.45*** | | | | | | | |
| SE ± (interaction) | 2.1* | | | | | | | |
| C.V. (%) | 7.16 | | | | | | | |

Rainfall use efficiency was highly significantly affected by cultivars. In this study, the improved early maturing cultivar possessed the higher rainfall use efficiency (5.10kg/ha/mm) than the late maturing one (Table 3). Generally, early maturing varieties have a strong advantage in yield over the late one when moisture is limited (Laing and Fischer, 1977).

Table 6. The interaction effect of seasons and methods of sowing on rainfall use efficiency (kg/ha/mm).

| Methods of sowing | 1st season (2010) | 2nd season (2011) | 3rd season (2012) | Mean | SE ± |
|---|---|---|---|---|---|
| Dry sowing | 3.13 | 0.84 | 13.7 | 5.91 | 0.41** |
| Wet sowing | 2.31 | 0.85 | 11.1 | 4.75 | |
| Deep dibbling | 3.12 | 0.80 | 9.34 | 4.44 | |
| Priming and fertilizer | 3.33 | 0.80 | 7.50 | 3.88 | |
| Mean | 2.97 | 0.84 | 10.4 | | |
| SE ± (season) | 0.34*** | | | | |
| SE ± (interaction) | 0.71** | | | | |
| C.V. (%) | 41.2 | | | | |

The sowing methods significantly affected the rainfall use efficiency. Dry sowing methods utilized the rain more than the others (Table 4). The significant interaction of seasons and methods of sowing revealed that dry sowing performed better in the season with high rainfall (2012) as this technique captured more rain. In much dry land environment, early sowing is usually one of the most reliable strategies to maximize the water use efficiency (Stappar and Harris, 1989).

However, the dibbling method showed constancy in performance across the different seasons of this study (Table 6). Tunner (2004) stated that increasing the depth of rooting is the major way to increase the water use of the crop by itself.

Table 7. The individual and combined grain yield (kg/ha) of pearl millet cultivars at Jebel Kordofan site during 2010–2012 seasons.

| Methods of sowing | Ashana | | | Dembi | | | Combined sowing methods | SE ± |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2010 | 2011 | 2012 | | |
| Dry sowing | 805.5 | 196.3 | 4690.0 | 731.0 | 163.3 | 3238.0 | 1637.0 | 115** |
| Wet sowing | 602.0 | 187.0 | 4105.0 | 524.0 | 173.8 | 2274.0 | 1311.0 | |
| Deep dibbling | 683.0 | 219.8 | 3559.0 | 841.0 | 149.8 | 1814.0 | 1211.0 | |
| Priming and fertilizer | 1017.0 | 195.7 | 2303.0 | 614.0 | 136.4 | 2021.0 | 1048.0 | |
| Yield per seasons | 777.3 | 199.7 | 3664.0 | 677.8 | 155.8 | 2337.0 | | |
| SE ± | $62.1^{ns}$ | 9.2* | 263* | | | | | |
| C.V.% | 44.0 | 15.8 | 30.7 | | | | | |
| Combined mean | | 1547 | | | 1056 | | | |
| SE ± | 79.3** | | | | | | | |
| C.V.% | 42.2 | | | | | | | |

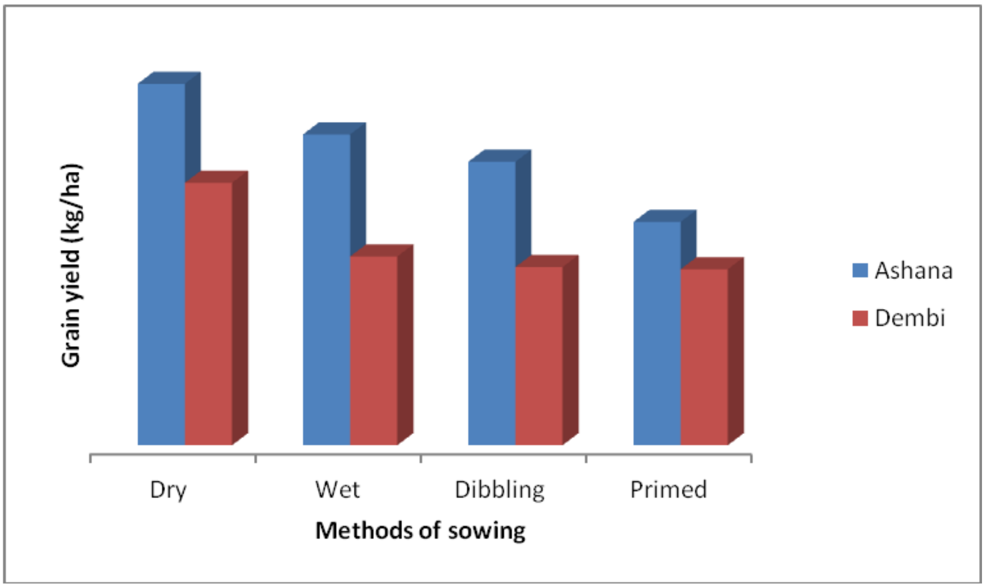


Figure 1. Millet cultivar yields under different sowing methods (during 2010–2012 seasons) at Jebel Kordofan area.

## Conclusion

The improved variety (Ashana) gave high water use efficiency, earliness and grain yield under rainfed conditions as compared with the local one (Dembi), hence, the improved cultivar is considered the most important agronomic option to improve rainfall use efficiency and yield of pearl millet in rain-fed areas. Dry sowing has a high probability of poor seedling emergence due to seed desiccation and damage by insect and rats when practiced by farmers (during late April and May). An improvement in this technique developed in this study is dry sowing between the last week of June and the second week of July with a seed dresser. This modified dry sowing significantly gave higher grain yield than the others.

As a conclusion, the agronomic options to increase the yield and rainfall use efficiency of pearl millet under rain fed areas are as follows: soil preparation by a chisel plough in gardud areas; selection of the early maturing cultivar; dry sowing (from the $4^{th}$ week of June to $2^{nd}$ week of July) and dibbling at 10 cm. It is recommended to use the modified dry sowing in the gardud area of pearl millet for high yield and better rainfall use efficiency.

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Received: October 21, 2019
Accepted: January 28, 2020

# UTICAJ TEHNIKA SETVE I PRODUKTIVNOST PADAVINA NA PRINOS PROSA CRNI MUHAR NA ZEMLJIŠTU GARDUD U SEVERNOM KORDOFANU

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R e z i m e

Crni muhar se gaji u sredinama koje su pogođena sušom. Očekuje se da će klimatske promene povećati osetljivost u svim agro-ekološkim zonama, kroz rastuće temperature i obilne padavine, što će imati drastične posledice na prehrambenu sigurnost. Crni muhar je žito koje ima veliki potencijal za obezbeđenje prehrambene sigurnosti i stvaranje prihoda na marginalnim područjima, zbog svoje pogodnosti gajenja i u ekstremnim uslovima poljoprivrede. Ovo studija je izvršena na eksperimentalnom lokalitetu Jebel Kordofan, u pokrajini Sheikan u državi Severni Kordofan tokom sezona 2010–2012. godine, kako bi se procenio uticaj različitih tehnika setve i padavina na produktivnost prinosa lokalnih i poboljšanih sorti prosa. Tretmani predstavljaju kombinaciju četiri tehnike setve i dve sorte crnog muhara. Tehnike setve su uključivale: suvu setvu, vlažnu setvu, duboku sadnju (na dubini od 10 cm) i potapanje sa mikrodoziranim đubrivom. Dve sorte su bile uključene: Ashana (poboljšana) i Dembi (lokalna). Ovi tretmani su bili raspoređeni po dizajnu podeljenih parcela, glavna parcela za sorte i potparcela za metode setve u četiri ponavljanja. Proučavani su parametri: dani do 50% cvetanja, visina biljke (cm), prinos zrna (kg/ha) i produktivnost padavina (kg/ha/mm). Sorte su pokazale visoko značajne razlike u odnosu na broj dana do 50% cvetanja, visinu biljke (cm), prinos zrna (kg/ha) i produktivnost padavina (kg/ha/mm). Tehnika suve setve značajno ($P \leq 0.05$) je dala je najviše biljke (149cm), veću efikasnost korišćenja vode (5, 10 kg/ha/mm) i najviši prinos zrna (1637 kg/ha). Može se zaključiti da je setvena parcela pripremljena čizel plugom i setva u suvom zemljištu dala najviši prinos zrna.

**Ključne reči:** tehnike setve, sorte prosa, efikasnost upotrebe padavina, prinos.

Primljeno: 21. oktobra 2019.
Odobreno: 28. januara 2020.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 47-60

https://doi.org/10.2298/JAS2001047A
UDC: 633.33(669)
Original scientific paper

# EFFECT OF PHOSPHORUS (P) RATES AND WEEDING FREQUENCY ON THE GROWTH AND GRAIN YIELD OF EXTRA EARLY COWPEA (*VIGNA UNGUICULATA* L. WALP) IN THE FOREST-SAVANNA AGRO-ECOLOGICAL ZONE OF SOUTHWEST NIGERIA

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**Abstract:** Field experiments were conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (7$^{o}$ 20’N, 3$^{0}$ 23’E) during the 2014 early and late cropping seasons to evaluate the effect of weeding frequency and phosphorus fertilizer application on the growth and grain yield of the early maturing cowpea variety (*Vigna unguiculata* L. Walp). The experiment was laid out in a split-plot arrangement fitted into a Randomized Complete Block Design with three replications. The main plot consisted of three phosphorus fertilizer rates (0, 15 and 30 $P_2O_5$kg ha$^{-1}$) while the subplot comprised five weeding frequencies (no weeding, weed-free, hoe weeding at 3 weeks after sowing (WAS), hoe weeding at 3 and 6 WAS and weeding at 3, 6 and 9 WAS). The results showed that plots treated with phosphorus fertilizer at 15 kg ha$^{-1}$ produced the highest number of leaves and the tallest plant in the late season while the highest grain yield was recorded in the early trials. Weeding at 3, 6 and 9 WAS during the early season trial gave the highest grain yield compared with other weeding treatments. Unchecked weed infestation reduced yield by 53.10 % and 49.9 % in the early and late seasons respectively compared to the maximum obtained from weed-free plots. This study concluded that application of 15 kg $P_2O_5$ ha$^{-1}$ and weed removal at 3, 6 and 9 WAS were effective for effective weed control and optimum grain yield in cowpea production.

**Key words:** cowpea, phosphorus fertilizer, weed biomass, weed infestation, weed species composition.

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## Introduction

Cowpea (*Vigna unguiculata* L. Walp) is one of the most important grain legumes in less developed countries of the tropics, particularly Asia and Africa (Mortimore et al., 1997; Van Ek et al., 1997). Cowpea has been reported to be grown on an estimated area of 12.3 million ha in Africa in 2014 with the bulk of production occurring on 10.6 million ha in West Africa, most especially Niger, Nigeria, Burkina Faso, Mali and Senegal (FAOSTAT, 2016). The world's estimated annual cowpea production is put at 5.4 million tonnes with Africa producing 5.2 million (Agro Nigeria, 2015). In 2010, Nigeria produced 2.2 million metric tonnes of cowpea production making it the largest producer and consumer of the crop with estimated yield put at 687 kg $ha^{-1}$ (FMARD, 2011) compared to the mean of 450 kilograms per hectare obtained globally.

Tarawali et al. (2002) have noted that cowpea has a significant role in contributing to food security, income generation and sustainable environment for millions of small-scale farmers who cultivate it in West Africa. The seed is the largest contributor to the overall protein intake of several rural and urban families (Agbogidi, 2010; Kyei-Boahen et al., 2017).

Cowpea fixes atmospheric nitrogen through symbiosis with nodule bacteria (Shiringani and Shimeles, 2011). The seed also contains bioactive antioxidants such as vitamin C, carotenoids and phenolic compounds which represent a crucial group of bioactive elements in foods that prevent the development of diseases such as atherosclerosis and cancer (Omae et al., 2011).

In spite of the great potential for cowpea in Southwest Nigeria, the yield of cowpea obtained by farmers is generally low due to high level of diseases, pest infestation (Adigun et al., 2014), lack of knowledge of good agricultural practices, use of low-yielding varieties coupled with low soil fertility and weed management problems (Adigun et al., 2014; Osipitan, 2017). Yield loss resulting from weed infestation in cowpea is often aggravated by the low level of soil nutrient particularly phosphorus. Weeds could cause yield losses ranging from 40% to 80% in cowpea (Tijani-Eniola, 2001; Li et al., 2004; Osipitan, 2017). Phosphorus plays a vital role in the growth and development of cowpea. Phosphorus deficiency in cowpea has also been reported to affect nodule formation, accumulation of N, seed formation as well as grain filling (Tang et al., 2001).

The timing of weed operation and availability of nutrient facilities in cowpea appear to be very vital in the determining the outcome of the competitive interaction between crop and weed as well as assisting the farmer to reduce the number of weeding on his/her farm, reduce the cost of production and maximize his/her profit. Das (2011) reported that the more abundant the soil nutrient, the less important the weed competition. However, in tropical soils, soils are low in nutrient and competition becomes critical. Moreover, applying fertilizer to improve crop yield will tend to provide maximum benefit unless weeds are properly managed.

Hand weeding is the most common agricultural practice among small-scale cowpea producers. The persistent use of manual weeding by cowpea farmers could be as a result of the high cost of herbicides which may not even be within their reach. Moreover, most farmers have not adequately timed their weed control with the use of fertilizer in cowpea. It should be noted that proper timing of weeding and fertilizer application can modify the weed flora and provide a platform for effective weed control.

Quite a number of research work done on the weed control in cowpea has not really addressed the interaction of P application and weeding frequency in cowpea. Hence, this research work is developed to investigate the growth and yield performance of the early maturing cowpea variety (IT97k-568-18) as influenced by the application of P fertilizer and weeding regime.

## Materials and Methods

The experiment was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta (Latitude $7^0$ $15^I$N, Longitude $3^0$ $25^I$E) in Southwest Nigeria during the early (April–July) and late (September–November) cropping seasons of 2014. The plot was cropped with maize in the previous season. The soil was sandy loam in texture with (84.4 g kg-1, 89.4g kg-1) sand, (4.8 kg-1, 5.8g kg-1) clay and (6.8 kg-1, 4.8g kg-1) silt particles in the early and late seasons respectively. The soil pH was moderate ranging between 6.65 and 5.65. However, the soil was very low in organic carbon (1.00% and 0.82%) and thus low in organic matter content and total nitrogen (0.08% and 0.10). Exchangeable potassium (0.23 cmol kg-1 and 0.17cmol kg-1) and available phosphorus (Bray -1 P) of the soil were low (6.02ppm and 8.75ppm). Exchangeable magnesium was low (0.90 cmol $kg^{-1}$ and 0.71cmol$kg^{-1}$), however exchangeable calcium was high (8.31 cmol $kg^{-1}$ and 5.12 c mol $kg^{-1}$).The climate of the study area is of the sub-humid type with the total amount of rainfall of 466.9 and 246 mm in the early and late seasons of 2014 respectively. The mean temperature was 26.75$^o$C and 26.97$^o$C in the early and late seasons respectively.

The early maturing cowpea variety (IT97k-568-18) used was sourced from the International Institute of Tropical Agriculture Ibadan, Oyo State, Nigeria. The experiment was a split-plot fitted into a Randomized Complete Block Design (RCBD) with three replicates, given a total number of 45 experimental units. The treatment consisted of the main plot of phosphorus rates at three levels: 0, 15 and 30kg $P_2O_5$ $ha^{-1}$ and the subplot of five weeding frequencies (weedy check, weed-free, weeding once at 3 weeks after sowing (WAS), weeding twice at 3 and 6 WAS and weeding thrice at 3, 6 and 9 WAS). Weedy- check in this study implies leaving the plot weed-infested throughout the crop life cycle (that is no weeding was applied) while weed-free was achieved by weeding the plot every week.

The experimental site in each crop cycle was ploughed and harrowed at the two-week interval and the land was marked out into various plots each measuring 5 m x 4 m. Three seeds of the cowpea variety (Var. IT97K-568-18) treated with CIBAPLUS were dibbled into the soil at a depth of 3–5 cm on the 18th of April 2014 for the early-season cowpea while the late-season crop was sown on the 5th of September 2014. The seeds were sown at a spacing of 50 cm x 20 cm (Dugje et al., 2009) and were thinned to 2 plants per stand two weeks after sowing (WAS). The seeds were sown at inter-row spacing of 50 cm and intra-row spacing of 20 cm between and within ridges respectively, representing 200,000 plants $ha^{-1}$. Hoe weeding was carried out according to the treatment structure using a West African hand hoe (a local farm tool that is used for weeding, ridging and heaping). Application of Cypermethrin plus Dimethoate was done every ten days beginning from 14 days after planting to control insects using a CP3 knapsack sprayer with a green deflector nozzle at a pressure of $2.1kg/cm^2$. Also, Mancozeb 80WP (fungicide) was applied at 4 WAS to prevent fungal diseases. Both the insecticide and the fungicide were applied at the rate of 0.6 L/ha. Harvesting of the early-season cowpea started on the 21st of June 2014 while harvesting of the late-season cowpea started on the 8th of November 2014.

Data were collected on plant height (cm), number of leaves/plant, leaf area ($cm^2$), number of days to 50% flowering, days to 50% podding, dry pod weight (kg/ha), number of seeds per pod, 100-grain weight of cowpea, grain yield of cowpea (kg $ha^{-1}$) and weed dry matter production. The data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Duncan's Multiple Range Test (DMRT).

## Results and Discussion

Weed-crop competition can be influenced by the time of weed removal and soil fertility maintenance. Generally, weeds have higher nutrient and water use efficiency, therefore a realistic weed management procedure and enhancement of the soil nutrient status will go a long way in enhancing the completive ability of the crop against weeds. The most noticeable significance of weed competition in crops is a reduction in the economic yield of the affected crop (Alagbejo, 1987; Dadari, 2003). The results of this study showed that application of fertilizer levels and weeding frequencies on cowpea influenced growth, yield and yield components, pod weight and the number of seed per pod as well as weed biomass and flora composition.

Effect of phosphorus fertilizer application and weeding frequencies on the growth and development of cowpea

Effects of phosphorus fertilizer rates and weeding frequencies on plant height and number of leaves of cowpea during the 2014 early and late cropping seasons are presented in Table 1. It was observed that application of phosphorus fertilizer had no significant effect on plant height at 3, 6 and 9 WAS during the early cropping season and at 3 WAS during the late cropping season (Table 1). However, plant height significantly differed from one another during the late season at 6 and 9 WAS, where the application of 15 and 30 kg $P_2O_5$ $ha^{-1}$ respectively gave similar and higher values compared with plots without phosphorus application. The effect of weeding frequencies was not significant on cowpea plant height in both cropping seasons. With respect to the cowpea number of leaves, a significant effect of phosphorus fertilizer application was observed only at 6 WAS during the late cropping season. Cowpea plants on plots treated with 15 and 30 kg $P_2O_5$ $ha^{-1}$ produced higher number of leaves than those plants on unfertilized plots. The effect of weeding frequencies was significant on the number of leaves at 6 and 9 WAS in the early cropping season and 9 WAS in the late cropping season. In both cases, all the weeding frequencies produced a significantly similar number of leaves compared with weedy check plots where reduced values were obtained. Interactions of phosphorus fertilizer rates and weeding frequencies were not significant on cowpea plant height and number of leaves at the various weeks of observation (Table 1). As presented in Table 2, cowpea responded to fertilizer application with respect to the leaf area at 6 WAS, but no significant effect was observed at 3 and 9 WAS. At 6 WAS cowpea plants on plots applied with 15 and 30 kg $P_2O_5$ $ha^{-1}$ had similar leaf area but significantly higher values than the control (0 kg $P_2O_5$ $ha^{-1}$. Weeding frequencies did not show any significant effect on the leaf area except at 6 and 9 WAS in the late season. Maximum and comparable leaf areas were recorded on the weed-free plots and the plots weeded at 3, 6 and 9 WAS at 6 and 9 WAS in the late season (Table 2). The increase in plant height and leaf production observed as a result of fertilizer application during the late season trial at 6 and 9 WAS could be attributed to the fact that the crop was able to utilize the residual nutrient in the soil. Furthermore, the higher number of leaves and leaf area could have allowed the greater reception of light which encouraged the photosynthetic process of the plants required for pod filling and improved yield. Similar findings have been reported by Muleba and Ezumah (1985) and Singh et al. (2011).

Table 1. Effects of weeding frequency and phosphorus fertilizer rates on plant height and number of leaves during the early and late wet seasons of 2014.

| Treatments | Plant height (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 3 WAS | | 6 WAS | | 9 WAS | |
| | Early | Late | Early | Late | Early | Late |
| Fertilizer (F) (kg/ha) | | | | | | |
| 0 | 12.47 | 14.20 | 65.80 | 40.80b | 96.10 | 81.40b |
| 15 | 11.51 | 15.23 | 64.61 | 47.33a | 95.00 | 96.47a |
| 30 | 10.99 | 14.79 | 64.05 | 50.32a | 95.00 | 95.38a |
| S.E (±) | 0.59* | 0.83 | 3.98 | 2.30** | 4.01 | 5.28* |
| P < 0.05 | 0.022 | 0.182 | 0.955 | 0.006 | 0.913 | 0.028 |
| Weeding frequency (W) | | | | | | |
| Weedy check | 11.87 | 15.3 | 64.82 | 44.19 | 95.2 | 100.77 |
| Weed-free | 11.56 | 15.56 | 65.04 | 49.92 | 95.2 | 90.69 |
| Weeding at 3 WAS | 11.70 | 14.01 | 66.84 | 48.49 | 97.3 | 85.42 |
| Weeding at 3 and 6 WAS | 11.76 | 13.67 | 61.96 | 43.17 | 92.3 | 87.24 |
| Weeding at 3, 6 and 9 WAS | 11.38 | 15.17 | 65.44 | 44.98 | 96.6 | 91.30 |
| S.E (±) | 0.76 | 1.07 | 5.14 | 2.97 | 5.17 | 6.82 |
| P < 0.05 | 0.922 | 0.360 | 0.824 | 0.386 | 0.797 | 0.139 |
| Fertilizer × Weeding frequency | | | | | | |
| S.E (±) | 1.32 | 1.85 | 8.91 | 5.15 | 8.96 | 11.80 |
| P > 0.05 | 0.973 | 0.650 | 0.581 | 0.561 | 0.670 | 0.596 |

Table 1. Continued.

| Treatments | Number of leaves (no./plant) | | | | | |
|---|---|---|---|---|---|---|
| | 3 WAS | | 6 WAS | | 9 WAS | |
| | Early | Late | Early | Late | Early | Late |
| Fertilizer (F) (kg/ha) | | | | | | |
| 0 | 9.25 | 5.87 | 28.97 | 22.57b | 50.69 | 33.47 |
| 15 | 9.03 | 5.87 | 28.39 | 28.45a | 49.75 | 39.61 |
| 30 | 8.85 | 6.03 | 32.36 | 26.72a | 57.87 | 40.52 |
| S.E (±) | 0.40 | 0.18 | 1.76 | 1.73* | 3.61* | 3.04* |
| P < 0.05 | 0.690 | 0.670 | 0.035 | 0.030 | 0.039 | 0.039 |
| Weeding frequency (W) | | | | | | |
| Weedy check | 9.07 | 6.16 | 19.22b | 23.56 | 31.38b | 29.98b |
| Weed-free | 9.31 | 6.07 | 33.98a | 26.51 | 60.64a | 42.53a |
| Weeding at 3 WAS | 9.07 | 5.82 | 33.36a | 26.16 | 59.64a | 39.16a |
| Weeding at 3 and 6 WAS | 8.89 | 5.64 | 31.44a | 26.84 | 56.00a | 38.11a |
| Weeding at 3, 6 and 9 WAS | 8.89 | 5.96 | 31.53a | 26.51 | 56.18a | 39.56a |
| S.E (±) | 0.58 | 0.24 | 2.27** | 2.24 | 4.67** | 3.92* |
| P < 0.05 | 0.979 | 0.233 | 0.001 | 0.492 | 0.001 | 0.034 |
| Fertilizer × Weeding frequency | | | | | | |
| S.E (±) | 0.10 | 5.87 | 3.93 | 3.87 | 8.08 | 6.80 |
| P > 0.05 | 0.526 | 0.724 | 0.488 | 0.530 | 0.621 | 0.128 |

WAS = Weeks after sowing, S.E = Standard error, p> 0.05= Not significant, *= Significant at p < 0.05, **= Highly significant at p< 0.01. Means followed by the different letter(s) within the same column and treatments are significantly different at 5% level of probability (DMRT).

Table 2. Effects of phosphorus fertilizer rates and weeding frequency on leaf area during the early and late wet seasons of 2014.

| Treatments | Leaf area ($cm^2$) | | | | | |
|---|---|---|---|---|---|---|
| | 3 WAS | | 6 WAS | | 9 WAS | |
| | Early | Late | Early | Late | Early | Late |
| Fertilizer (F) (Kg/ha) | | | | | | |
| 0 | 20.70 | 9.20 | 38.30b | 41.80b | 58.28 | 30.20 |
| 15 | 18.30 | 10.20 | 45.70a | 45.50a | 56.49 | 34.40 |
| 30 | 22.50 | 12.30 | 49.60a | 47.20a | 61.42 | 33.20 |
| S.E (±) | 2.31ns | 2.23ns | 2.58** | 1.69* | 2.38 | 2.06 |
| P < 0.05 | 0.163 | 0.265 | 0.001 | 0.050 | 0.163 | 0.068 |
| Weeding frequency (W) | | | | | | |
| Weedy check | 20.60 | 11.4 | 39.10 | 41.50b | 59.19 | 24.8c |
| Weed-free | 22.00 | 11.90 | 43.30 | 47.30a | 59.14 | 35.3ab |
| Weeding at 3 WAS | 19.50 | 11.60 | 46.60 | 45.70ab | 57.85 | 30.9b |
| Weeding at 3 and 6 WAS | 19.10 | 8.00 | 48.10 | 42.20b | 57.36 | 36.7a |
| Weeding at 3, 6 and 9 WAS | 21.40 | 10.10 | 45.60 | 47.50a | 60.10 | 35.3ab |
| S.E (±) | 2.98 | 2.88 | 3.90 | 2.19* | 3.07 | 2.27** |
| P < 0.05 | 0.781 | 0.479 | 0.057 | 0.05 | 0.781 | 0.001 |
| Fertilizer × Weeding frequency | | | | | | |
| S.E (±) | 5.17 | 4.98 | 6.76 | 4.44 | 5.32 | 4.60 |
| P > 0.05 | 0.330 | 0.196 | 0.176 | 0.902 | 0.330 | 0.100 |

Fertilizer rates significantly affected the number of days to 50% flowering during the early and late cropping seasons. A delayed number of days to 50% flowering was observed in both seasons when phosphorus fertilizer was increased from 15 kg $P_2O_5$ $ha^{-1}$ to 30 kg $P_2O_5$ $ha^{-1}$ compared to no fertilizer treated plots (Table 3). However, weeding frequencies did not have a significant effect on days to 50% flowering and days to 50% podding in the early and late cropping seasons (Table 3).

Effects of phosphorus fertilizer application and weeding frequencies on cowpea yield and yield components

Cowpea pod and grain yield were significantly affected by fertilizer rates in the early season but not in the late season (Table 4). Application of 15 kg $P_2O_5$ $ha^{-1}$ gave pod and grain yields in the early season which were very similar to the maximum values obtained from plots treated with 30 kg $P_2O_5$ $ha^{-1}$ (Table 4). However, there were no significant effects of phosphorus fertilizer on the number of seeds per pod and 100-grain weight in both early and late season trials. Weeding frequencies significantly affected cowpea pod yield in early and late seasons (Table 4). Weeding at 3, 6 and 9 WAS gave significantly higher pod yield but similar to the weed-free in the early season. In the late season, though weeding thrice ranked highest with respect to pod yield, it was not significantly different from the weed-free, weeding once and weeding twice (Table 4). In the same vein, weeding at 3, 6 and 9 WAS gave the maximum and comparable grain yield and comparable values with weed-free plots. There was no significant interaction between fertilizer rate and weeding frequency on pod yield, number of seeds/pods, 100-grain weight and grain yield.

Table 3. Effects of phosphorus fertilizer rates and weeding frequency on the number of days to 50% flowering and numbers of days to 50% podding during the early and late wet seasons of 2014.

| Treatments | Number of days to 50% flowering | | Number of days to 50 % podding | |
|---|---|---|---|---|
| | Early | Late | Early | Late |
| Fertilizer (F) (kg/ha) | | | | |
| 0 | 43b | 43b | 52.67 | 52.67 |
| 15 | 45ab | 43b | 52.80 | 52.73 |
| 30 | 46a | 44a | 52.07 | 53.00 |
| S.E (±) | 0.20* | 0.10* | 0.37 | 0.10 |
| P < 0.05 | 0.048 | 0.031 | 0.135 | 0.031 |
| Weeding frequency (W) | | | | |
| Weedy check | 44 | 44 | 52.11 | 52.78 |
| Weed-free | 45 | 44 | 53.00 | 52.78 |
| Weeding at 3 WAS | 45 | 44 | 52.56 | 52.78 |
| Weeding at 3 and 6 WAS | 44 | 44 | 52.44 | 52.78 |
| Weeding at 3, 6 and 9 WAS | 45 | 44 | 52.44 | 52.89 |
| S.E (±) | 0.36 | 0.82 | 0.48 | 0.21 |
| P < 0.05 | 0.482 | 0.815 | 0.801 | 0.816 |
| Fertilizer × Weeding frequency | | | | |
| S.E (±) | 0.63 | 1.42 | 0.83 | 0.37 |
| P > 0.05 | 0.924 | 0.923 | 0.780 | 0.923 |

The highest grain yield and yield characters such as pod yield recorded by the application of 30 kg P ha$^{-1}$could be attributed to the fact that cowpea responded to the application of phosphorus fertilizer. Similar research findings have been obtained by Okeleye and Okelana (1997) and Majeed et al. (2001). Reduction in cowpea yield in the early season compared to that of the late season could be attributed to the rainfall pattern during the period, which was higher than the one in the late season. This is in agreement with the report of Coulibaly and Lowenberg-DeBoer (2002), who documented that cowpea performed well in agro-ecological zones where rainfall distribution ranges between 500 mm and 1,200 mm/year. Therefore, the higher values recorded for yield and yield components of cowpea in the late season than early season could be attributed to the fact that rainfall during the growing period (September to November) was adequate and optimum in the late season. However, in the early season, excessive rainfall aggravated the preponderance of pest and diseases. This study, hence, showed that timely weed removal is important in cowpea production. Adigun et al. (1991) observed that the period between 3 and 6 WAS is particularly critical for weed removal in the wet season due to vigorous weed growth and competition with the crops. It is also worth noting that weed-free plot recorded lower grain yield than the plants on the plots weeded at 3, 6 and 9 WAP in the early season. Flower abortion and destruction of the crop roots at the time of weeding could have accounted for this lower yield in the weed-free plot. In the late season, on the contrary, weeding regimes irrespective of the time of weed removal gave similar effects on the grain yield.

Table 4. Effects of phosphorus fertilizer rates and weeding frequency on pod yield, number of seeds/pods, 100 grain weight and grain yield in the early and late wet seasons of 2014.

| Treatments | Pod yield (kg/ha) | | Number of seeds/pod | | 100-grain weight (g) | | Grain yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|
| | Early | Late | Early | Late | Early | Late | Early | Late |
| Fertilizer (F) kg/ha | | | | | | | | |
| 0 | 608.4b | 884.22 | 12.03 | 14.35 | 13.60 | 16.80 | 405.60b | 646.30 |
| 15 | 811.3a | 918.59 | 11.93 | 13.25 | 13.93 | 17.60 | 622.00a | 659.33 |
| 30 | 755.3a | 1089.19 | 12.33 | 13.77 | 14.13 | 17.80 | 585.60a | 797.26 |
| S.E (±) | 68.65* | 116.77 | 0.28 | 0.63 | 0.37 | 0.53 | 59.50* | 96.41 |
| P ≤ 0.05 | 0.020 | 0.414 | 0.255 | 0.570 | 0.234 | 0.601 | 0.029 | 0.114 |
| Weeding frequency (W) | | | | | | | | |
| Weedy check | 531.50c | 543.80b | 12.20 | 13.23 | 14.22 | 17.00 | 361.10d | 416.00b |
| Weed-free | 820.40ab | 1131.40a | 12.28 | 14.06 | 14.00 | 18.56 | 610.50b | 830.50a |
| Weeding at 3 WAS | 709.30bc | 1043.20a | 11.59 | 13.37 | 14.22 | 16.56 | 528.60bc | 715.30a |
| Weeding at 3 and 6 WAS | 621.00c | 1013.60a | 12.16 | 13.42 | 13.56 | 17.11 | 417.50cd | 736.50a |
| Weeding at 3, 6 and 9 WAS | 943.10a | 1088.00a | 12.27 | 14.87 | 13.56 | 17.78 | 770.90a | 806.40a |
| S.E (±) | 88.63* | 150.75* | 0.36 | 0.82 | 0.47 | 0.68 | 76.80** | 124.47** |
| P ≤ 0.05 | 0.002 | 0.002 | 0.237 | 0.274 | 0.373 | 0.294 | 0.012 | 0.001 |
| Fertilizer ×Weeding frequency | | | | | | | | |
| S.E (±) | 153.51 | 261.10 | 0.63 | 1.42 | 0.82 | 1.18 | 132.90 | 215.59 |
| P > 0.05 | 0.603 | 0.365 | 0.392 | 0.331 | 0.893 | 0.410 | 0.700 | 0.480 |

Uncontrolled weed infestation throughout the crop life cycle in this study resulted in about 50% to 53% reduction in potential grain yield of cowpea. The significantly high percentage yield reduction could be attributed to the fact that the cowpea crop is sensitive to weed competition, especially in Nigerian savanna agroecological zones as indicated by Magani (1990). Moreover, the field was highly infested with broadleaf weeds such as *Tridax procumbens, Phyllanthus amarus* and these weeds are known to compete adversely with the cowpea crop. This finding was in conformity with the report of Li et al. (2004), who stated that yield losses ranging between 50% and 86% could occur due to unchecked weed growth throughout the life cycle in cowpea. It is, thus, become imperative that early weeding should be done to guarantee a higher yield in cowpea. Adigun et al. (2014) have observed that early weeding starting from 3 WAS is very crucial for cowpea production while the critical period of weed removal for optimum yield in cowpea is between 3 and 9 WAS in the forest-savannah transitional zone of Southwest Nigeria.

Effects of phosphorus fertilizer rates and weeding frequency on weed dry matter production

In the early and late seasons, the fertilizer rates did not have a significant effect on weed biomass throughout the weeks of observation except at 6 WAS during the late-season trial (Table 5).

Table 5. Effects of phosphorus fertilizer rates and weeding frequency on weed dry weight during early and late wet seasons of 2014.

| Treatments | Weed dry weight (kg/ha) | | | |
|---|---|---|---|---|
| | 6 WAS | | 9 WAS | |
| | Early | Late | Early | Late |
| Fertilizer (kg/ha) | | | | |
| 0 | 641.95 | 284.60ab | 1284.83 | 390.77 |
| 15 | 297.58 | 429.10a | 595.17 | 276.03 |
| 30 | 471.74 | 154.30b | 943.65 | 388.43 |
| S.E (±) | 179.60 | 103.31* | 359.18 | 172.33 |
| $P \leq 0.05$ | 0.222 | 0.043 | 0.222 | 0.630 |
| Weeding frequency (W) | | | | |
| Weedy check | 1492.20a | 912.70a | 2984.50a | 1064.10a |
| Weed-free | 57.40b | 79.20b | 116.20b | 157.40b |
| Weeding at 3 WAS | 335.20b | 66.30b | 670.30b | 198.40b |
| Weeding at 3 and 6 WAS | 287.60b | 222.00b | 575.20b | 242.70b |
| Weeding at 3, 6 and 9 WAS | 179.70b | 169.60b | 359.90b | 96.20b |
| S.E (±) | 231.87** | 133.37** | 463.71** | 222.48** |
| $P \leq 0.05$ | 0.001 | 0.001 | 0.001 | 0.003 |
| Fertilizer × Weeding frequency | | | | |
| SE (±) | 401.61 | 231.01 | 803.17 | 385.35 |
| $P > 0.05$ | 0.796 | 0.076 | 0.795 | 0.614 |

In the late-season trial, fertilizer application significantly affected weed dry matter with the application of 15 kg $P_2O_5$ $ha^{-1}$ giving the highest weed dry matter which was similar to the value obtained with no fertilizer application. Application of 30 kg $P_2O_5$ $ha^{-1}$ gave the least dry matter production. Weed dry matter was significantly reduced by 77.6, 80.7 and 87.9% when weeding was carried out once at 3 WAS, twice at 3 and 6 WAS and thrice at 3, 6 and 9 WAS respectively. In the late season, on the other hand, weed dry matter was reduced by 81.4, 77.2 and 90.9 % in the plot weeded at 3 WAS, 3 and 6 WAS and 3, 6 and 9 WAS respectively

(Table 5). Higher weed biomass was recorded during the late season trial at 6 WAS when the plots were treated with 15 kg $P_2O_5$ $ha^{-1}$ High weed relative density of *Cyperus esculentus* (12.29%), *Dactylotenum aegyptium* (13.65%), *Digitaria horizontalis* (21.84%) and *Kyling abulbosa* (8.19 %) observed on these plots at the early stage of crop growth at the second peak of rain in the ecology could have accounted for the increased weed biomass. These weed species were known to have higher competitive ability than field crops in the rainforest and savanna ecology (Adeyemi et al., 2008).

## Conclusion

Application of phosphorus fertilizer at 15 kg $P_2O_5$ $ha^{-1}$ and weed removal at 3 and 6 weeks after planting in the late season are appropriate and adequate for cowpea production in the forest-savannah transitional zone of Southwest Nigeria. Hoe weeding at 3, 6, and 9 WAS significantly ($p < 0.05$) reduced weed biomass by 85% compared to control plots while application of 15 kg $P_2O_5$ $ha^{-1}$ increased grain yield by 34.8 and 30.7 % in early and late seasons, respectively. The use of phosphorus fertilizer and timely weed removal are, thus, a *sine qua non* in promoting weed control effectiveness in cowpea and improving grain yield.

## Acknowledgements

The authors are grateful to the undergraduate students who assisted in collection data on the field and the Laboratory Technologists of the Department of Plant Physiology and Crop Production, Federal University of Agriculture Abeokuta, Nigeria.

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Received: March 31, 2019
Accepted: November 25, 2019

# UTICAJ KOLIČINA FOSFORA (P) I UČESTALOSTI PLEVLJENJA NA RAST I PRINOS ZRNA VRLO RANE VIGNE (*VIGNA UNGUICULATA* L. WALP) U ŠUMSKO-SAVANSKOJ AGRO-EKOLOŠKOJ ZONI JUGOZAPADNE NIGERIJE

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R e z i m e

Poljski ogledi su sprovedeni na Nastavno-istraživačkom imanju Federalnog poljoprivrednog univerziteta u Abeokuti (7$^{o}$ 20'N, 3$^{0}$ 23'E) tokom 2014. rane i kasne sezone gajenja (dve sezone), kako bi se procenio uticaj učestalosti plevljenja i primene fosfornog đubriva na rast i prinos zrna rane sorte vigne (*Vigna unguiculata* L. Walp). Ogled je postavljen po rasporedu podeljenih parcela uklopljenom u potpuno slučajni blok dizajn sa tri ponavljanja. Glavna parcela se sastojala od tri količine fosfornog đubriva (0, 15 i 30 $P_2O_5$kg ha$^{-1}$) dok je potparcela obuhvatala pet učestalosti plevljenja (bez plevljenja, održavanje parcele čistom plevljenjem motikom 3 nedelje posle setve, plevljenje motikom 3 i 6 nedelja posle setve i plevljenje 3, 6 i 9 nedelja posle setve). Rezultati su pokazali da su biljke gajene na parceli tretirane fosfornim đubrivom od 15 kg ha$^{-1}$ proizvele najveći broj listova i najveću visinu biljke u kasnoj sezoni, dok je najviši prinos zrna zabeležen kod gajenja vigne u ranoj sezoni. Plevljenje 3, 6 i 9 nedelja posle setve tokom ispitivanja u ranoj sezoni dalo je najviši prinos zrna u poređenju sa ostalim tretmanima plevljenja. Na parcelama na kojima nije primenjivana mera kontrole korova smanjen je prinos za 53,10% i 49,9% u ranoj odnosno kasnoj sezoni u poređenju sa maksimalnim prinosom dobijenim sa parcela bez korova. Ovim istraživanjem se zaključuje da su primena đubriva od 15 kg $P_2O_5$ ha$^{-1}$ i mehaničko suzbijanje korova 3, 6 i 9 nedelja posle setve najefikasnije mere kontrole korova i dobijanja optimalnih prinosa zrna u proizvodnji vigne.

**Ključne reči:** vigna, fosforno đubrivo, biomasa korova, zakorovljenost, sastav korovskih vrsta.

Primljeno: 31. marta 2019.
Odobreno: 25. novembra 2019.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 61-68

https://doi.org/10.2298/JAS2001061P
UDC: 665.353.4
665.347.8
Original scientific paper

# QUALITY PARAMETERS OF SUNFLOWER OIL AND PALM OLEIN DURING MULTIPLE FRYING

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**Abstract:** The refined sunflower and palm oils are used in the food industry for the production of fried potatoes. Literary data have shown that palm oil had less tendency to degradation than sunflower oil due to its fatty acid composition. However, palm olein is a palm oil fraction and therefore has a different composition of fatty acids. The aim of this study was to investigate the quality of the refined palm olein in relation to the refined linoleic type sunflower oil during the production of fried potatoes. The oil samples were used for multiple frying during the seven days (40 minutes per day at a temperature of 165°C). The peroxide value and free fatty acid content (acid value) were determined by standard analytical methods. The results showed that the peroxide value in sunflower oil and palm olein increased by 75.0% and 77.8%, while the acid value increased by 50.0% and 26.8%, respectively, in relation to their initial values in the fresh oil samples. Based on these results, it can be concluded that the palm olein was more suitable for frying. However, this finding cannot be reported with certainty because the quality of the oil depends on many more parameters, not only on those analysed in this paper.

**Key words:** sunflower oil, palm olein, peroxide value, acid value.

## Introduction

Potato frying is a widespread way of preparing potatoes for human consumption. The fried potatoes have a pleasant taste and a crunchy texture that make them very popular with consumers. The most common method of frying potatoes is deep frying in oil in the food industry as well as in the household. In industrial conditions, frying oil is used for a long period of time before being

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replaced by a new one. The time and high frying temperatures, the presence of moisture and oxygen affect the initiation of chemical and physical changes that deteriorate the oil quality. Numerous volatile and non-volatile compounds are formed in the processes of hydrolysis, oxidation, isomerisation and polymerisation (Choe and Min, 2007). It is very important which kind of oil will be selected for frying, so oils that have more saturated fatty acids in their composition are significantly more stable than those with more unsaturated fatty acids (Grompone, 2005; Matthäus, 2007). As potatoes absorb a certain amount of oil (up to 40%) during frying, a number of undesirable newly formed compounds affect the fried potato quality. Thus, the taste and acceptability of fried potato are deteriorated, but it also becomes unsafe to the health of the consumers. Kita et al. (2005) point out that fried potatoes absorbed less fat by increasing frying temperatures. It is very important to choose the right type of oil that can maintain quality during frying for a long period of time. The most commonly used oils for the industrial potato frying in our country are sunflower and palm oils, or a palm oil fraction (palm olein).

Refined sunflower oil is produced by pressing and extracting sunflower seeds (Grompone, 2005). According to Crapiste et al. (1999), extracted sunflower oil showed a higher oxidative stability in relation to cold-pressed sunflower oil during storage. The dominant fatty acid in standard (linoleic type) sunflower oil is a linoleic, polyunsaturated, omega-6 fatty acid, followed by an oleic fatty acid, while the linolenic acid content is always less than 0.3%. The low content of linolenic acid is positive because this fatty acid contributes most to the oxidative instability of the oil (Grompone, 2005). Among the saturated fatty acids, palmitic and stearic acids are present in an amount not exceeding 15%. Also, this oil is a rich source of tocopherols, especially alfa-tocopherol (Grompone, 2005).

Malaysia is the world's largest producer of palm oil (Basiron, 2007). Palm oil is obtained by pressing the mesocarp of the palm oil tree fruit (Lin, 2011). Palm oil has approximately the same ratio of saturated and unsaturated fatty acids. Palmitic and oleic acids are the predominant fatty acids, with linoleic and trace amounts of linolenic acid (Lin, 2011; Pande et al., 2012). The high content of saturated fatty acids and the negligible content of linolenic acid make this oil oxidatively stable (Pande et al., 2012). Palm oil contains a significantly higher amount of tocopherols, tocotrienols, carotenoids and chlorophylls in comparison to sunflower oil, and therefore it is oxidatively more stable (Edem, 2002; Pande et al., 2012; Mba et al., 2015). The synergistic effect of β-carotene and tocotrienols can reduce oxidation during potato slice frying at a temperature of 163°C (Pande et al., 2012; Mba et al., 2015). Due to the presence of carotenoid and chlorophyll pigments, palm oil, unlike sunflower oil, has a darker colour. Phospholipids were found in smaller quantities than in other vegetable oils. Similarly, palm oil contains a small amount of phenolic compounds that are responsible for oil browning during frying (Pande et al., 2012). Palm olein is a liquid fraction obtained during the palm oil fractionation process, which involves crystallisation at controlled temperatures and removal of crystals by filtration (Lin, 2011; Pande et al., 2012). Palm olein is different from palm oil in that it has a higher oleic than palmitic acid content.

The aim of this study was to investigate the quality of the refined sunflower oil and palm olein during the multiple deep frying of potatoes.

## Materials and Methods

The material for this experiment was purchased at a retail store in Belgrade, Serbia. Refined standard sunflower oil was originally from Serbia, and palm oil fraction (palm olein) originated from Malaysia. Potatoes were produced in Serbia.

Sample preparation. Potatoes (500 g per batch) were cut into sticks and frying was done in two open deep fryers (3 L of oil per fryer), at a temperature of 165$^{o}$C for a total of 40 minutes (4 minutes per batch of potatoes). The frying process was repeated for seven days (one 40-minute frying per day for both oils, without oil replenishment), and samples of both oils were taken after the first, third, fifth and seventh day of frying. Between frying, the oil was stored in the fryers but with the lids closed. The time interval between the two fryings was about 24 h.

All post-frying and fresh oil samples were compared by standard analytical methods for determination of the peroxide number (peroxide value – PV) and the acid number (acid value – AV). There were ten samples in total: sunflower oil sample before frying (SO), sunflower oil sample taken after the first (SO1), third (SO3), fifth (SO5) and seventh (SO7) frying; palm olein sample before frying (PO), palm olein sample taken after the first (PO1), third (PO3), fifth (PO5) and seventh (PO7) frying.

The peroxide value (PV) [SRPS EN ISO 660:2015], expressed in mmol/kg, was determined by the reaction of oil and chloroform: acetic acid (3:2) with potassium iodide in darkness. The free iodine was then titrated with thiosulfate solution.

The acid value (AV) [SRPS EN ISO 3960:2016], expressed in mg KOH/g, was determined by the titration of a solution of oil dissolved in ethanol: ether (1:1) with an ethanolic solution of potassium hydroxide.

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

## Results and Discussion

The results of peroxide and acid values of sunflower oil and palm olein samples before and during potato frying are given in Table 1.

Table 1. The peroxide value (PV) and the acid value (AV) of sunflower oil and palm olein samples before and during potato frying.

| Samples | AV (mg KOH/g) | PV (mmol/kg) |
|---|---|---|
| SO | $0.28^{c} \pm 0.008$ | $2.00^{c} \pm 0.004$ |
| SO1 | $0.28^{c} \pm 0.016$ | $2.30^{c} \pm 0.008$ |
| SO3 | $0.28^{c} \pm 0.008$ | $2.50^{c} \pm 0.016$ |
| SO5 | $0.35^{c} \pm 0.012$ | $3.25^{cb} \pm 0.000$ |
| SO7 | $0.42^{cb} \pm 0.008$ | $3.50^{cb} \pm 0.004$ |
| PO | $0.56^{ba} \pm 0.012$ | $2.25^{c} \pm 0.008$ |
| PO1 | $0.64^{a} \pm 0.000$ | $4.50^{cba} \pm 0.000$ |
| PO3 | $0.71^{a} \pm 0.008$ | $6.50^{a} \pm 0.004$ |
| PO5 | $0.71^{a} \pm 0.000$ | $5.50^{ba} \pm 0.008$ |
| PO7 | $0.71^{a} \pm 0.004$ | $4.00^{cba} \pm 0.000$ |

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

Based on these results, it can be seen that palm olein had the free fatty acid content significantly higher in comparison to sunflower oil before frying. Furthermore, the free fatty acid content in sunflower oil and palm olein increased by 50.0% and 26.8% after seven days of frying, respectively, in relation to their initial values in the fresh oil samples. The free fatty acid content in palm olein increased immediately after the first frying, and had constant values after the third frying, while sunflower oil had an increase of the free fatty acid content only after the third frying, but subsequently tended to increase. In the study of Gunnepana and Nawaratne (2015), it was observed that palm olein also had higher values of free fatty acids compared to sunflower oil before the frying process and that both oils showed an increase in the free fatty acid content during multiple frying. Also, according to published results of Gunnepana and Nawaratne (2015), a sudden increase in the free fatty acid content in palm olein after the first frying can be observed. When the acidity of the oil is significantly increased, it is a sign that hydrolytic reactions of the lipids have taken place, resulting in the cleavage of ester bonds and the separation of free fatty acids. Oils with a high content of free fatty acids have a foreign, unpleasant, soapy-acidic and pungent taste (Ebba et al., 2012).

In auto-oxidative processes under the effect of oxygen, light, elevated temperature, moisture and heavy metal ions, the chain reaction in oils produces very reactive peroxides. They can be polymerised and, at higher temperatures, decomposed to carbonyl compounds which contribute to the rancid taste and aroma (Kaleem et al., 2015).

Based on the results obtained in this experiment, it can be concluded that sunflower oil and palm olein had a significant increase in the peroxide value after seven days of frying. Both oils had a similar peroxide value before and after frying. The difference was that palm olein had a significantly faster increase in the peroxide value until the third frying, and after that, it showed a decrease of this parameter. The decrease in the peroxide value of palm olein can be explained by the fact that peroxides can evaporate, decompose and react with other compounds during deep frying (Choe and Min, 2006; Alhibshi et al., 2016). Unlike palm olein, sunflower oil had a gradual increase in the peroxide value during all seven days of frying. The results showed that the peroxide value in sunflower oil and palm olein increased by 75.0% and 77.8%, respectively, in relation to their initial values in the fresh oil samples. Slightly different results can be observed in the research of Gunnepana and Nawaratne (2015). Both oils had a gradual increase in the peroxide value during multiple frying, but palm olein had a significantly higher content of the peroxide value than sunflower oil at the very beginning of the experiment, which in particular affected this parameter increase during frying. According to Gunnepana and Nawaratne (2015), palm olein had neither a sudden increase nor a sudden decrease in the peroxide value.

De Marco et al. (2007) compared the quality of pure palm oil and the blend of sunflower/palm oil (65/35 vol/vol) during potato frying. The selected blend showed a higher tocopherol content and a lower increment in free fatty acids in relation to pure palm oil, but the other parameters which indicate quality deterioration increased faster in the blend (De Marco et al., 2007). In the research of Aladedunye and Przybylski (2014), high-oleic sunflower oil showed a significantly higher frying stability in relation to palm olein during frying at 185°C for 6 days.

Multiple frying affected the quality of sunflower oil and palm olein. Also, alternating heating and cooling caused the deterioration of oil quality because the oxygen solubility increases in the oil when the oil cools down from the frying temperature (gases are more soluble in liquids at the lower temperature) (Choe and Min, 2007). Based on these results, it can be concluded that palm olein was more suitable for frying. However, this finding cannot be reported with certainty because the quality of the oil depends on many more parameters (water and other volatile compound contents, oil alkalinity, solvent residue, oxidative stability, etc.), not only on those analysed in this paper.

## Conclusion

The chemical reactions of hydrolysis, oxidation, isomerisation and polymerisation during deep frying contribute to the deterioration of the oil quality. Numerous compounds are formed such as, among others, free fatty acids and peroxides. In addition to the type of oil, the change in the quality was affected by the period of frying. The results showed that acid values for sunflower oil and palm olein increased by 50.0% and 26.8%, respectively, in relation to their initial values in the fresh oil samples, but palm olein had a higher initial free fatty acid content compared to sunflower oil. The peroxide value in sunflower oil and palm olein increased by 75.0% and 77.8%, respectively, in relation to their initial values in the fresh oil samples. Although palm olein had a greater increase in the peroxide value, a decrease in the peroxide value was observed during frying, unlike sunflower oil, where this parameter had a constant increase. Based on these results, it could be concluded that the palm olein was in some respect more suitable for frying. However, this finding cannot be reported with certainty because the quality of the oil depends on many more parameters, not only on those analysed in this paper.

### Acknowledgements

This work was supported by the Ministry of Education and Science of the Republic of Serbia (Grant Nos. 46001, 46010 and 31020).

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Received: November 14, 2019
Accepted: January 28, 2020

# PARAMETRI KVALITETA SUNCOKRETOVOG ULJA I PALMINOG OLEINA TOKOM VIŠESTRUKOG PRŽENJA

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R e z i m e

U prehrambenoj industriji se za proizvodnju prženog krompira koriste rafinisano suncokretovo i palmino ulje. Prema literaturnim podacima, palmino ulje ima manju sklonost ka degradacionim promenama u odnosu na suncokretovo ulje, zahvaljujući sastavu masnih kiselina. Međutim, palmin olein je frakcija palminog ulja i samim tim ima drugačiji sastav masnih kiselina. Cilj ovog rada bio je da se ispita kvalitet rafinisanog palminog oleina u odnosu na rafinisano suncokretovo ulje tokom proizvodnje prženog krompira. Uzorci ulja su korišćeni za višestruko prženje tokom sedam dana (po 40 minuta svakog dana, na temperaturi od 165$^{o}$C). Peroksidni broj i sadržaj slobodnih masnih kiselina (kiselinski broj) određeni su standardnim analitičkim metodama. Rezultati su pokazali da se peroksidni broj u suncokretovom ulju i palminom oleinu povećao 75,0% odnosno 77,8%, dok se kiselinski broj povećao 50,0% odnosno 26,8%, u odnosu na početne vrednosti u uzorcima svežeg ulja. Na osnovu ovih rezultata može se zaključiti da je palmin olein pogodniji za prženje. Međutim, ovaj zaključak se ne može navesti sa sigurnošću jer kvalitet ulja zavisi od mnogo više parametara, a ne samo od onih analiziranih u ovom radu.

**Ključne reči:** suncokretovo ulje, palmin olein, peroksidni broj, kiselinski broj.

Primljeno: 14. novembra 2019.
Odobreno: 28. januara 2020.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 69-84

https://doi.org/10.2298/JAS2001069G
UDC: 631.15(497.11)"2009/2018"
Original scientific paper

# TENDENCIES OF PLANT PRODUCTION IN THE REPUBLIC OF SERBIA AND AT THE LEVEL NUTS 1

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**Abstract:** In this paper, we analyzed the tendencies of plant production in the Republic of Serbia and at the level of the territorial units Serbia-North and Serbia-South (NUTS 1), for the period 2009–2018 through the indicators of the coverage of areas and an average yield of 28 plant crops. The aim of the paper is to point out the differences in the representation of areas under different types of crops and to indicate the degree of their agreement between the mentioned territorial units by Spearman's correlation coefficient. For the analysis of the observed indicators, the methods of descriptive statistics, as well as Spearman's correlation coefficient, were used. The data indicate that the Serbia-North region is dominated by areas under cereals, industrial crops, peas and peaches, while the Serbia-South region is covered by areas under fodder crops, vegetable crops (potatoes, tomatoes, peppers, onion, garlic, beans, cucumber, melons and watermelons) and perennial crops. The average yields of the observed crops differ significantly between the regions of Serbia-North and Serbia-South. Spearmen's correlation coefficient of the indicators of the coverage of areas indicated a high degree of stacking of areas under wheat and tobacco (0.927**), as well as areas under lucerne and clover with areas under fruit plantations. Also, a high degree of stacking of areas under maize and peas (0.798**) was established, but also between areas under sunflower and soya (0.891**).

**Key words:** plant production, crops, utilized land, NUTS 1, indicators.

## Introduction

Plant production accounts for 1.53 billion hectares and represents about 12% of Earth's ice-free land (Foley et al., 2011). The importance of plant products in agricultural production and trade stems from the fact that they are essential in the daily diet of humans and animals (Roljević Nikolić et al., 2019). The rapid growth in world population has also led to a significant increase in crop production in recent decades. Foley et al. (2011) state that crop production, observed at the global level, increased by 28% between 1985 and 2005, with areas under crops increasing by 2.4% and average yields by 25%.

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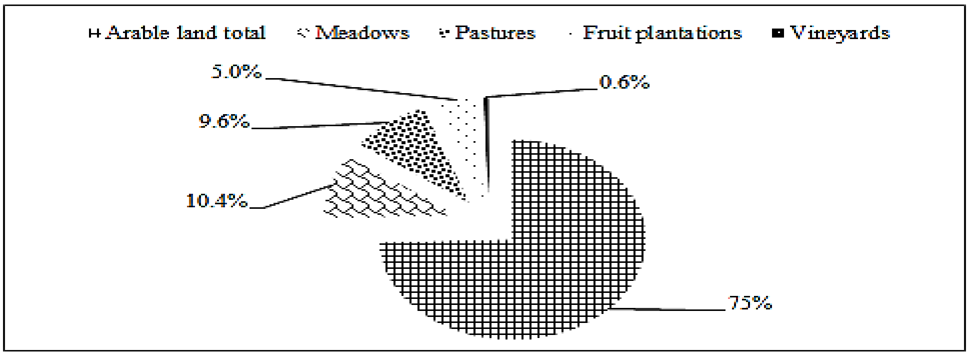
Thanks to favorable agro-ecological conditions and tradition, agriculture has been one of the most important sectors of the Serbian economy (Milošević et al., 2015). In addition to providing food security for the population, it is a major source of raw materials for a number of industrial capacities (Vasiljević et al., 2011) and has a high share in the formation of total GDP (Popović, 2009). The largest share in the structure of value of agricultural production is crop production (about 67%), i.e. crop and vegetable crops, which are cultivated at over 3 mln ha (Strategy of Agriculture and Rural Development of the Republic of Serbia for the period of 2014–2024).

However, the organizational and legal structure and size of agricultural holdings significantly affect the productivity of agriculture in Serbia. According to the Census of Agriculture 2012 (Book I), published by the Statistical Office of the Republic of Serbia in 2013, out of the total number of agricultural holdings (631,552), only 0.5% are households of legal entities and entrepreneurs (3,000). It is concluded that the structure of registered agricultural holdings is dominated by family farms, which is recognized as one of the factors that has a strong influence on fluctuations in the production of main crops in Serbia (Munćan, 2017; Munćan et al., 2014). In addition, the participation of a large number of smallholder farms limits the application of modern agro-technical measures, which is reflected in the low level of agricultural production productivity (Maletić and Popović, 2016; Todorović et al., 2010).

On the other hand, different natural, social and economic conditions as well as tradition in the production of certain products influence the diversification and concentration of arable production in certain areas (Todorović, 2018). Thus, 58% of maize production and 56% of total wheat production in Serbia are concentrated in the Vojvodina region (Novković et al., 2013).

The utilized agricultural area (UAA), as the most important production resource, covers 3,437,423 ha, accounting for almost 40% of the total territory of Serbia (Census of Agriculture, 2012). The high quality of agricultural land, favorable agro-ecological conditions and well-positioned trading location give significant comparative advantages to our country's agriculture (Filipović et al., 2013). In the structure of the UAA is dominated by arable land and gardens with 75.5%, followed by orchards with 5.3%, vineyards with 0.6%, meadows with 9.4% and pastures with 8.6% (SORS, 2017). The sowing structure of arable land and gardens is dominated by cereals that cover 66.2% of these areas. Considering that maize is the most commonly seated crop on the arable land, the area under maize in 2017 was 0.8% less than in 2015. Accordingly, the share of area under maize in arable land in 2017 was 38.6%, which is 0.4 p.p. less compared to 2015 (39%). Figure 1 shows the structure of the UAA in 2018.

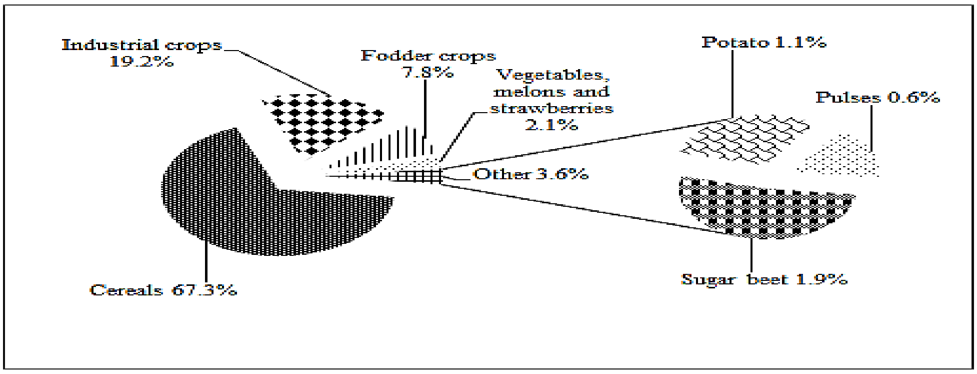



Source: SORS, Database and authors' calculation.

Figure 1. The structure of the UAA in 2018.

By comparing the structure of the UAA in 2017 and 2018, it can be concluded that the share in arable land and fruit plantations in 2018 was reduced in comparison with 2017, while the share of areas under meadows and pastures was slightly increased. The areas under vineyards remained unchanged in both observed years.

The structure of the arable land in 2018 (Figure 2) shows the largest participation of cereals with 67.3%, then the area under industrial crops with 19.2%. Potatoes, pulses and sugar beets covered only 3.6% of arable land. Furthermore, in 2018, the most common crop was maize, which participated with 35.5% in the total of arable land.




Source: SORS, Database and authors' calculation.

Figure 2. The structure of the arable land in 2018.

Observing the region of Serbia-North in a total of UAA in 2017, arable land and gardens participated with 91.5%, fruit plantation with 2.1%, vineyards with 0.3%, meadows with 1.5% and pastures with 4.2%. The area under cereals occupied 63.1% in the total of arable land, and the most commonly seated crop was maize with a share of 61.9%, while in the total of arable land it had a share of 39%. The area under maize in 2017, compared to 2015, was lower by 9,551 ha or by 1.5%. Except for maize, wheat, sunflower and soya had a significant part in the arable land.

Regarding the area of Serbia-South, the structure of the UAA is different from the region of Serbia-North, and in 2017 it looked like this: arable land and gardens occupied 60.1%, fruit plantations 8.6%, vineyards 0.9%, meadows 17.1% and pastures 12.9%. Although the share of arable land and gardens in the UAA was lower comparing to the North of Serbia, the areas under the cereals in the South of Serbia had a higher share in the arable land compared to the North of Serbia and accounted for 70.4%. The most common crop was maize, which in 2017 compared to 2015was increased by 1,643 ha or by 0.4%. Except for maize, wheat, lucerne, clover and vegetable crops also had a significant share in the arable land.

In accordance with the given results on the territory of the Republic of Serbia, the most represented areas were under arable land and gardens. Analyzing at the level of NUTS 1, there were differences whereby arable land and gardens were the dominant representation in the region of Serbia-North, while the areas under meadows and pastures were mostly located in the region of Serbia-South.

## Materials and Methods

In this paper, the data were used from the Statistical Office of the Republic of Serbia for the period 2009–2018, and the indicators of the presence of areas and average yield of 28 plant crops: wheat, barley, maize, rapeseed, sugar beets, sunflower, soya, tobacco, potatoes, tomatoes, peas, cabbage and kale, onion, peppers, beans, melons and watermelons, cucumber, garlic, lucerne, clover, apples, pears, plums, grapes, strawberries, raspberries, sour cherries and peaches were analyzed. The realized yields and areas were analyzed at the level of the Republic of Serbia and at the level of the two territorial units – Serbia-North and Serbia-South. Data were processed using descriptive statistics (arithmetic mean, standard deviation, variance and interval of variation). Also, the table view of the representation of analyzed crops at the level NUTS 1 is given. To determine the strength and direction of connection between surfaces under selected crops, Spearman’s coefficient of correlation of ranks was used. In accordance with the obtained results, adequate comments and conclusions were given. For the purposes of these analyses, the software package SPSS 25 was used.

## Results and Discussion

In Table 1, the review of the basic statistical indicators of crop yield in the Republic and two regions – North and South, achieved in the period 2009–2018, is given.

Cereals are the most important source of food globally since they provide as much as 50% of the total calories to the world population (Popović and Kovljenić, 2017). In the Republic of Serbia, cereals are the leading plant products in both sowing structure and production volume. Looking at the structure of the UAA at the Republic level, it can be observed that maize recorded the highest share (29.15%). The average yield of maize in the ten-year period at the Republic level was 6.1 t $ha^{-1}$. It was lower compared to the North (6.9 t $ha^{-1}$) and higher in relation to the South region (4.9 t $ha^{-1}$). The highest and lowest maize yield values were recorded in the North part of Serbia, ranging from 3.9 t $ha^{-1}$ to 8.8 t $ha^{-1}$, slightly lower in the Republic (from 3.6 t $ha^{-1}$ to 7.7 t $ha^{-1}$), while the interval of yield was the lowest in the southern part of Serbia (from 3.1 t $ha^{-1}$ to 6 t $ha^{-1}$).

Except for cropping, vegetable cropping is equally important. Accordingly, the highest value of the yield of cucumber was recorded in the South of Serbia with an interval of variation from 12.8 t $ha^{-1}$ to 18 t $ha^{-1}$. The same yield was recorded at the level of the Republic of Serbia, while the lowest yield was recorded in the North of Serbia and ranged from 11.1 t $ha^{-1}$ to 15 t $ha^{-1}$. The yield variation interval of beans was similar to all three levels of observation and ranged from 0.8 t $ha^{-1}$ to 1.4 t $ha^{-1}$, while the average yield was the highest in the northern part of Serbia and amounted to 1.2 t $ha^{-1}$.

Forage crops have an important role in the development of livestock production and, consequently, in improving the competitiveness of agricultural holdings (Todorović et al., 2010). The highest average yield of lucerne and clover was recorded in the northern part of Serbia, and the smallest in the territory of the South of Serbia. The yield variation interval of lucerne had identical values on the territory of the Republic (min 2.9 t $ha^{-1}$, max 4.5 t $ha^{-1}$) and Serbia-South (min 2.7 t $ha^{-1}$, max 4.4 t $ha^{-1}$), while the northern part of Serbia recorded the highest yield values (min 3.2 t $ha^{-1}$, max 5.1 t $ha^{-1}$). The north of Serbia also stood out in terms of the yield of lucerne which reached the maximum value of up to 6.9 t $ha^{-1}$.

Although there are very favorable natural conditions for the cultivation of a large number of continental fruit species in Serbia, production potential has not yet been adequately utilized. Due to its predominantly extensive character, fruit production in Serbia has been stagnant or even declining for a long time (Bulatović Lukač et al., 2013).

Having in mind the smaller representation of fruit and vineyard production in the North of Serbia, the spreadsheet leads to the conclusion that, for example, strawberries and sour cherries have higher yields in the southern part of Serbia, and the lowest in the North of Serbia.

Table 1. Basic statistical indicators of crop yield in the Republic of Serbia and regions of Serbia-North and Serbia-South (2009–2018).

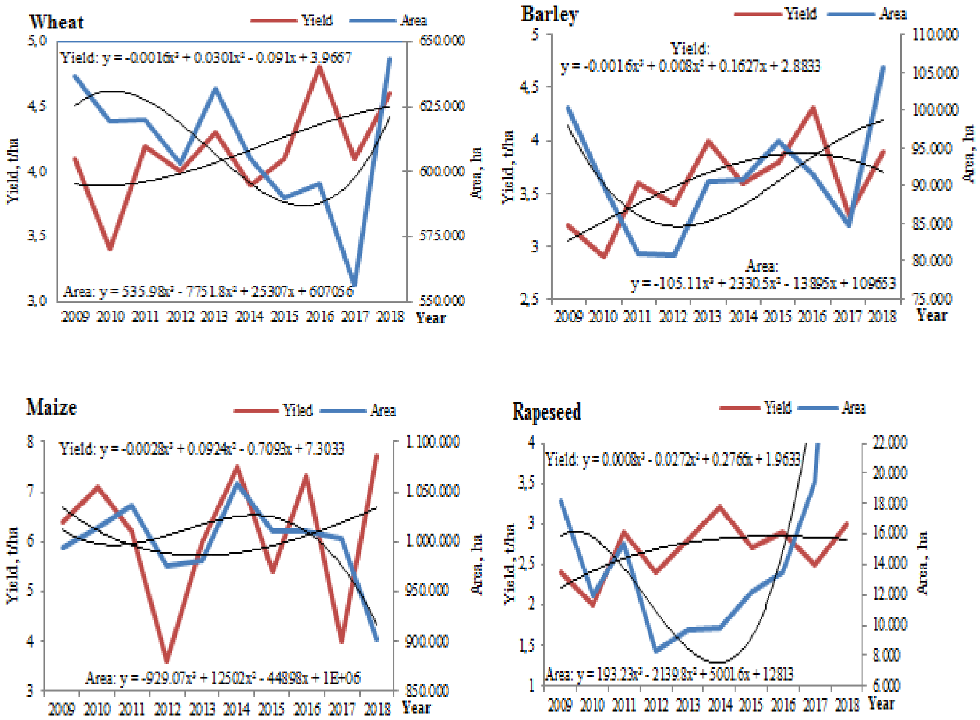
| Crop | Republic of Serbia | | | | | Serbia-North | | | | | Serbia-South | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Variance | Min | Max | Mean | Std. Deviation | Variance | Min | Max | Mean | Std. Deviation | Variance | Min | Max |
| Wheat | 4.15 | 0.38 | 0.15 | 3.4 | 4.8 | 4.71 | 0.56 | 0.31 | 3.7 | 5.8 | 3.42 | 0.21 | 0.04 | 3 | 3.7 |
| Barley | 3.60 | 0.42 | 0.17 | 2.9 | 4.3 | 4.14 | 0.47 | 0.22 | 3.3 | 4.9 | 3.1 | 0.40 | 0.16 | 2.5 | 3.9 |
| Maize | 6.12 | 1.42 | 2.02 | 3.6 | 7.7 | 6.9 | 1.68 | 2.81 | 3.9 | 8.8 | 4.9 | 1.03 | 1.07 | 3.1 | 6 |
| Rapeseed | 2.68 | 0.36 | 0.13 | 2.0 | 3.2 | 2.76 | 0.38 | 0.14 | 2 | 3.3 | 2.15 | 0.34 | 0.11 | 1.8 | 2.9 |
| Sugar beet | 48.60 | 5.41 | 29.25 | 35.9 | 54.7 | 48.74 | 5.42 | 29.41 | 36 | 54.9 | 23.21 | 3.78 | 14.31 | 15.6 | 27.2 |
| Sunflower | 2.60 | 0.36 | 0.13 | 2.0 | 3.1 | 2.65 | 0.39 | 0.15 | 2 | 3.2 | 2.08 | 0.36 | 0.13 | 1.5 | 2.6 |
| Soya | 2.72 | 0.57 | 0.32 | 1.7 | 3.5 | 2.73 | 0.58 | 0.34 | 1.7 | 3.6 | 2.29 | 0.47 | 0.22 | 1.6 | 2.9 |
| Tobacco | 1.58 | 0.21 | 0.05 | 1.2 | 1.9 | 1.61 | 0.21 | 0.05 | 1.3 | 1.9 | 1.53 | 0.28 | 0.08 | 1.1 | 2 |
| Potato | 15.33 | 2.33 | 5.42 | 11.1 | 17.8 | 19.77 | 2.67 | 7.14 | 14.2 | 22.1 | 13.82 | 2.37 | 5.61 | 9.8 | 16.7 |
| Tomato | 17.51 | 2.46 | 6.06 | 13.9 | 20.7 | 21.43 | 2.37 | 5.63 | 16.7 | 24.5 | 15.12 | 3.18 | 10.10 | 11.8 | 19.3 |
| Peas | 5.18 | 0.80 | 0.64 | 3.8 | 6.1 | 6 | 1.03 | 1.05 | 4.7 | 7.1 | 3.82 | 0.56 | 0.32 | 2.6 | 4.5 |
| Cabbage and kale | 25.87 | 1.47 | 2.16 | 23.5 | 27.9 | 29.24 | 2.33 | 5.45 | 25 | 32.2 | 24.62 | 1.32 | 1.74 | 21.9 | 26.6 |
| Onion | 8.01 | 1.62 | 2.63 | 6.0 | 12.1 | 11.06 | 1.89 | 3.58 | 8.4 | 15.3 | 6.09 | 1.46 | 2.12 | 4.6 | 9.9 |
| Peppers | 9.84 | 1.87 | 3.51 | 7.4 | 13.4 | 11.43 | 2.33 | 5.41 | 6.9 | 14.6 | 9.35 | 1.86 | 3.47 | 7.6 | 13 |
| Beans | 1.09 | 0.13 | 0.02 | 0.8 | 1.2 | 1.22 | 0.18 | 0.03 | 0.8 | 1.4 | 1.03 | 0.11 | 0.01 | 0.8 | 1.2 |
| Melons and watermelons | 31.50 | 3.73 | 13.94 | 26.6 | 37.4 | 39.41 | 7.52 | 56.58 | 27.9 | 51 | 24.28 | 1.88 | 3.55 | 21 | 26.8 |
| Cucumber | 14.56 | 1.68 | 2.83 | 12.6 | 17.0 | 13.68 | 1.37 | 1.88 | 11.1 | 15 | 14.95 | 2.05 | 4.19 | 12.8 | 18 |
| Garlic | 2.89 | 0.48 | 0.23 | 2.2 | 3.8 | 3.7 | 0.69 | 0.48 | 2.9 | 5 | 2.57 | 0.39 | 0.16 | 2 | 3.3 |
| Lucerne | 5.05 | 0.67 | 0.45 | 4.0 | 5.9 | 5.99 | 0.92 | 0.85 | 4.6 | 6.9 | 4.56 | 0.55 | 0.30 | 3.7 | 5.3 |
| Clover | 3.69 | 0.59 | 0.35 | 2.9 | 4.5 | 4.35 | 0.57 | 0.32 | 3.2 | 5.1 | 3.57 | 0.61 | 0.37 | 2.7 | 4.4 |
| Apples | 16.32 | 2.84 | 8.06 | 10.3 | 21.5 | 20.48 | 4.69 | 22.04 | 11.3 | 27.3 | 13.81 | 2.67 | 7.13 | 9.4 | 18.3 |
| Pears | 10.11 | 1.88 | 3.52 | 6.6 | 13.1 | 11.26 | 2.73 | 7.47 | 6.7 | 16.2 | 9.67 | 1.70 | 2.89 | 6.6 | 11.8 |
| Plums | 5.51 | 1.23 | 1.51 | 3.8 | 7.9 | 9.08 | 2.32 | 5.39 | 4.7 | 11.8 | 5.2 | 1.21 | 1.46 | 3.7 | 7.6 |
| Grapes | 7.92 | 1.36 | 1.86 | 5.8 | 10.6 | 8.27 | 1.52 | 2.32 | 5.8 | 11 | 7.8 | 1.32 | 1.75 | 5.8 | 10.4 |
| Strawberries | 5.19 | 1.16 | 1.35 | 3.2 | 6.9 | 3.94 | 0.76 | 0.57 | 2.3 | 4.8 | 5.67 | 1.50 | 2.25 | 3.5 | 8 |
| Raspberries | 6.17 | 0.92 | 0.84 | 5.0 | 7.6 | 5.76 | 1.63 | 2.67 | 2.8 | 7 | 6.17 | 1.04 | 1.07 | 4.9 | 7.8 |
| Sour cherries | 7.27 | 1.60 | 2.56 | 5.2 | 10.1 | 9.24 | 2.36 | 5.57 | 6.9 | 13.6 | 6.77 | 1.47 | 2.17 | 4.9 | 9.9 |
| Peach | 11.22 | 1.35 | 1.83 | 8.0 | 12.6 | 12.91 | 1.75 | 3.06 | 9.3 | 14.8 | 9.33 | 1.21 | 1.46 | 6.7 | 11.2 |

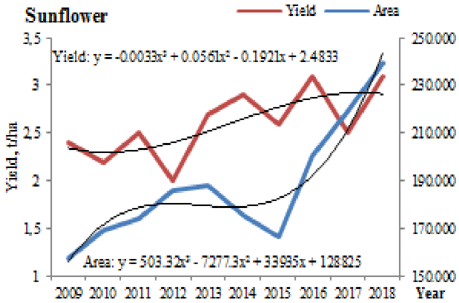
Source: SORS, Database and authors' calculation.

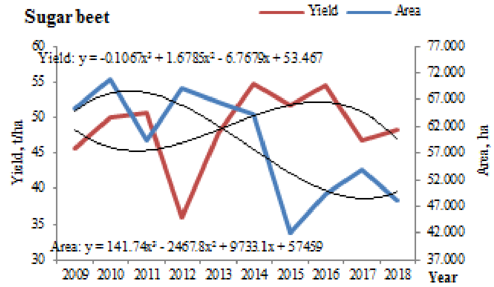
Although the Republic of Serbia has favorable natural conditions for agriculture, it is important to mention the most frequent causes for reducing yields:

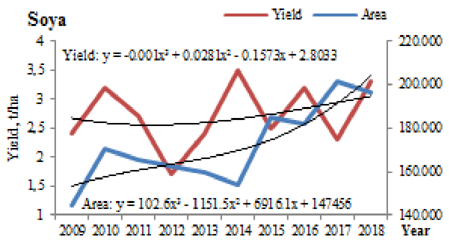
sowing out of the optimal period, inadequate application of agrotechnical measures, agrotechnical measures are performed with a delay because of outdated mechanization, unfavorable climatic conditions in certain stages of vegetation, inadequate cultivation technology and so forth. In other words, the level of yield does not depend entirely on weather conditions, but implies a set of many factors that must ensure the traceability of certain activities and processes. Values of agricultural outputs are mostly determined by agricultural capacities and climatic conditions (Joksimović et al., 2018).

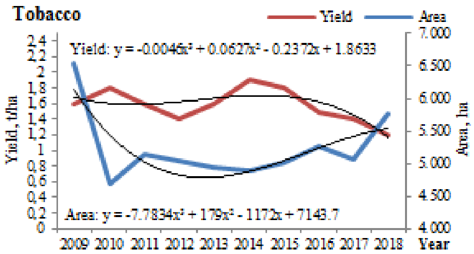
The trend of lines in Figure 3 describes the type and character of the movement of cultivated area and the yield of selected plant crops in the territory of the Republic of Serbia for the period of 2009–2018. From the graphical representation, we can see that the changes in the areas under a particular crop did not proportionally affect the yield changes. In other words, an increase in the area under a certain plant crop did not generate an increase in yield.

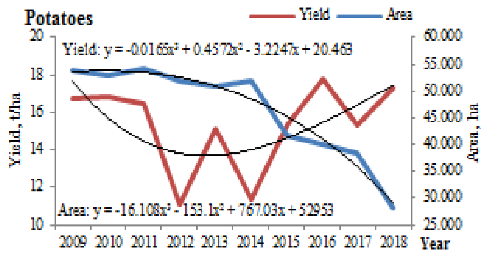


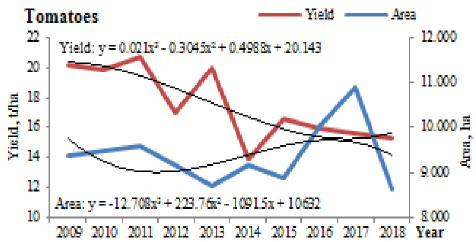

Sunflower
Yield
Area
Yield: $y = -0.0033x^3 + 0.0561x^2 - 0.1921x + 2.4833$
Area: $y = 503.32x^3 - 7277.3x^2 + 33935x + 128825$
Yield, t/ha
Area, ha
3,5
3
2,5
2
1,5
1
250.000
230.000
210.000
190.000
170.000
150.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year

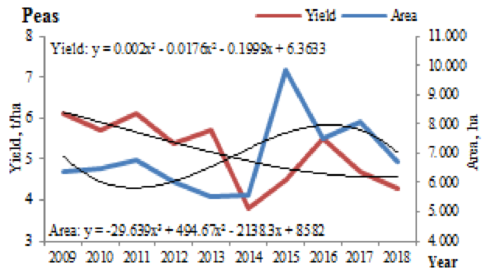

Sugar beet
Yield
Area
Yield: $y = -0.1067x^3 + 1.6785x^2 - 6.7679x + 53.467$
Area: $y = 141.74x^3 - 2467.8x^2 + 9733.1x + 57459$
Yield, t/ha
Area, ha
60
55
50
45
40
35
30
77.000
72.000
67.000
62.000
57.000
52.000
47.000
42.000
37.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year

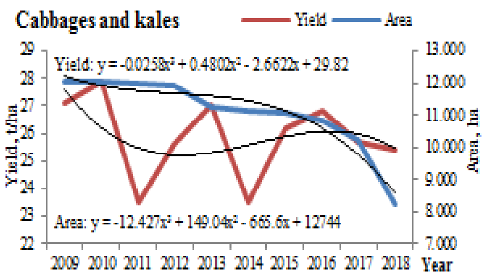

Soya
Yield
Area
Yield: $y = -0.001x^3 + 0.0281x^2 - 0.1573x + 2.8033$
Area: $y = 102.6x^3 - 1151.5x^2 + 6916.1x + 147456$
Yield, t/ha
Area, ha
4
3,5
3
2,5
2
1,5
1
220.000
200.000
180.000
160.000
140.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year

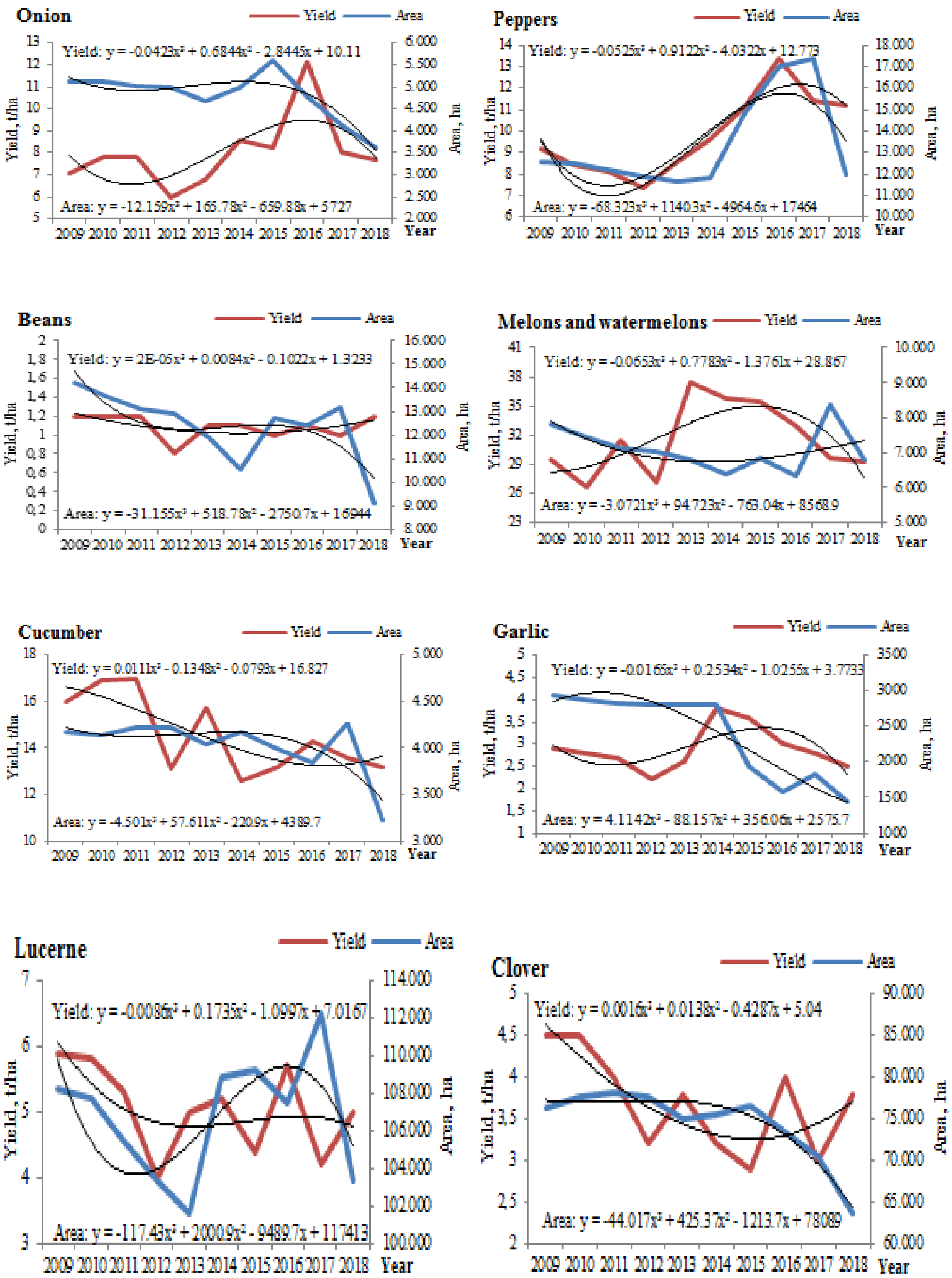

Tobacco
Yield
Area
Yield: $y = -0.0046x^3 + 0.0627x^2 - 0.2372x + 1.8633$
Area: $y = -7.7834x^3 + 179x^2 - 1172x + 7143.7$
Yield, t/ha
Area, ha
2,4
2,2
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
7.000
6.500
6.000
5.500
5.000
4.500
4.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year

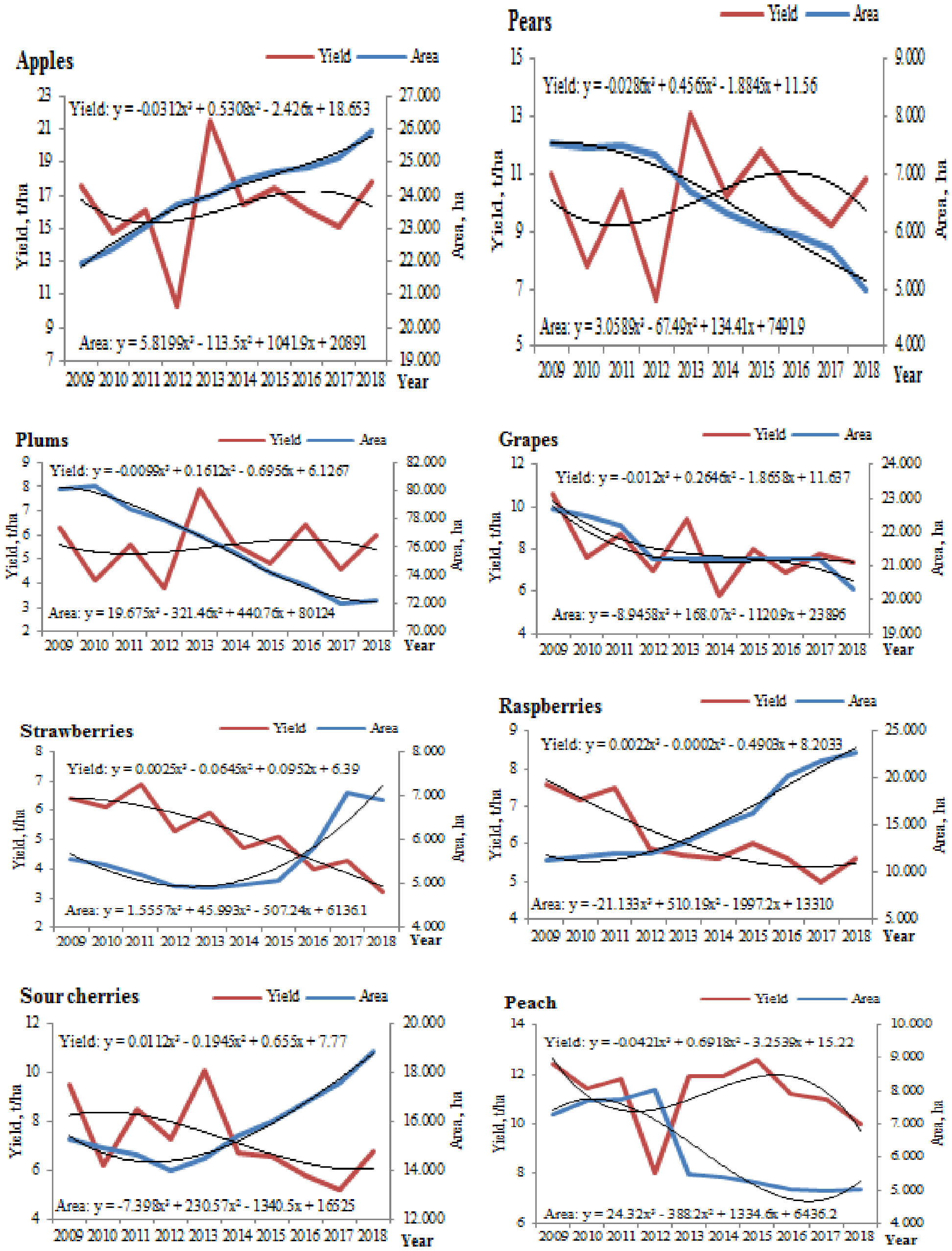

Potatoes
Yield
Area
Yield: $y = -0.0165x^3 + 0.4572x^2 - 3.2247x + 20.463$
Area: $y = -16.108x^3 - 153.1x^2 + 767.03x + 52953$
Yield, t/ha
Area, ha
20
18
16
14
12
10
60.000
55.000
50.000
45.000
40.000
35.000
30.000
25.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year


Tomatoes
Yield
Area
Yield: $y = 0.021x^3 - 0.3045x^2 + 0.4988x + 20.143$
Area: $y = -12.708x^3 + 223.76x^2 - 1091.5x + 10632$
Yield, t/ha
Area, ha
22
20
18
16
14
12
10
12.000
11.000
10.000
9.000
8.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year


Peas
Yield
Area
Yield: $y = 0.002x^3 - 0.0176x^2 - 0.1999x + 6.3633$
Area: $y = -29.639x^3 + 494.67x^2 - 2138.3x + 8582$
Yield, t/ha
Area, ha
8
7
6
5
4
3
11.000
10.000
9.000
8.000
7.000
6.000
5.000
4.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year


Cabbages and kales
Yield
Area
Yield: $y = -0.0258x^3 + 0.4802x^2 - 2.6622x + 29.82$
Area: $y = -12.427x^3 + 149.04x^2 - 665.6x + 12744$
Yield, t/ha
Area, ha
29
28
27
26
25
24
23
22
13.000
12.000
11.000
10.000
9.000
8.000
7.000
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year


Onion
Yield: y = -0.0423x³ + 0.6844x² - 2.8445x + 10.11
Area: y = -12.159x³ + 165.78x² - 659.88x + 5727
Peppers
Yield: y = -0.0525x³ + 0.9122x² - 4.0322x + 12.773
Area: y = -68.323x³ + 1140.3x² - 4964.6x + 17464
Beans
Yield: y = 2E-05x³ + 0.0084x² - 0.1022x + 1.3233
Area: y = -31.155x³ + 518.78x² - 2750.7x + 16944
Melons and watermelons
Yield: y = -0.0653x³ + 0.7783x² - 1.3761x + 28.867
Area: y = -3.0721x³ + 94.723x² - 763.04x + 8568.9
Cucumber
Yield: y = 0.0111x³ - 0.1348x² - 0.0793x + 16.827
Area: y = -4.501x³ + 57.611x² - 220.9x + 4389.7
Garlic
Yield: y = -0.0165x³ + 0.2534x² - 1.0255x + 3.7733
Area: y = 4.1142x³ - 88.157x² + 356.06x + 2575.7
Lucerne
Yield: y = -0.0086x³ + 0.1735x² - 1.0997x + 7.0167
Area: y = -117.43x³ + 2000.9x² - 9489.7x + 117413
Clover
Yield: y = 0.0016x³ + 0.0138x² - 0.4287x + 5.04
Area: y = -44.017x³ + 425.37x² - 1213.7x + 78089
Yield
Area
Yield, t/ha
Area, ha
Year




Source: SORS, Database and authors' calculation.

Figure 3. The movement of cultivated areas and yields of selected plant crops in the Republic of Serbia (2009–2018).

In Table 2, the overview of the average areas under a certain plant crop in the regions of Serbia-North and Serbia-South is given for the ten-year period. A region with a larger average area under a certain plant crop is marked.

Table 2. The overview of the average areas in the Serbia-North and Serbia-South regions (2009–2018).

| Crop | Serbia-North | Serbia-South | Crop | Serbia-North | Serbia-South |
|---|---|---|---|---|---|
| Wheat | ✓ | | Beans | | ✓ |
| Barley | | ✓ | Melons, watermelons | | ✓ |
| Maize | ✓ | | Cucumber | | ✓ |
| Rapeseed | ✓ | | Garlic | | ✓ |
| Sugar beet | ✓ | | Lucerne | | ✓ |
| Sunflower | ✓ | | Clover | | ✓ |
| Soya | ✓ | | Apples | | ✓ |
| Tobacco | ✓ | | Pears | | ✓ |
| Potato | | ✓ | Plums | | ✓ |
| Tomato | | ✓ | Grapes | | ✓ |
| Peas | ✓ | | Strawberries | | ✓ |
| Cabbage and kale | | ✓ | Raspberries | | ✓ |
| Onion | | ✓ | Sour cherries | | ✓ |
| Peppers | | ✓ | Peach | ✓ | |

Source: SORS, Database and authors' calculation.

Table 2 shows that the Serbia-North region dominates regarding the average area under cereals (except for barley areas) and industrial crops. On the one hand, the average area under maize in the North of Serbia (614,745.1 ha) was 1.6 times higher than the average area in the South of Serbia. The highest difference was recorded in sugar beet, where in the Serbia-North region the average area under sugar beet was 187.3 times higher (58,546.8 ha) than in Serbia-South region (only 312.5 ha). On the other hand, the average area under barley in the South of Serbia (46,103.7 ha) was 1,046.9 ha larger than in the North region.

More areas under vegetables, fodder crops and perennial crops are in the Serbia-South region (except for areas under peas and peaches). In the Serbia-South region, dominant areas are under potatoes (34,228.3 ha), peppers (10,164.5 ha), beans (8,986.7 ha), cabbage and kale (8,072.6 ha) and tomatoes (5,862.7 ha). The average area under clover was 5.3 times higher in the South (62,594.6 ha) than in the North of Serbia, while the areas under lucerne were on average 69,366.9 ha in the South of the country and in the North of Serbia were 37,361.9 ha. Also, the results show that the areas under plums were 10.4 times larger in the South compared to the Serbia-North region.

Generally, an equal distribution of plant crops enables timely supplying of food products to all parts of Serbia, with continuous development increasing both areas and yield.

Finally, with the Spearman's coefficient in Table 3, a comparative overview of areas under a certain plant crop is given in order to determine the degree of their stacking.

Table 3. The results of the correlation analysis of stacking areas under selected crops (2009–2018).

| Crop | Wheat | Barley | Maize | Rapeseed | Sugar beet | Sunflower | Soya | Tobacco | Potato | Tomato | Peas | Cabbage and kale | Onion | Peppers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | 1.000 | .720** | .846** | .741** | .743** | .737** | 654** | .927** | .371* | .396* | 800** | .429* | .406* | 0.243 |
| Barley | .720** | 1.000 | .615** | .432* | 0.290 | .388* | .362* | .738** | .564** | .615** | 627** | .600** | .644** | .657** |
| Maize | .846** | .615** | 1.000 | .646** | .703** | .685** | 681** | .863** | .426* | .478** | 875** | .436* | .486** | 0.345 |
| Rapeseed | .741** | .432* | .646** | 1.000 | .502** | .759** | 827** | .778** | -0.073 | 0.142 | 798** | -0.017 | 0.054 | 0.101 |
| Sugar beet | .743** | 0.290 | .703** | .502** | 1.000 | .584** | 464** | .674** | 0.126 | 0.034 | 512** | 0.156 | 0.050 | -0.166 |
| Sunflower | .737** | .388* | .685** | .759** | .584** | 1.000 | 891** | .753** | -0.062 | 0.183 | 730** | -0.011 | 0.055 | 0.078 |
| Soya | .654** | .362* | .681** | .827** | .464** | .891** | 1.000 | .695** | -0.107 | 0.169 | 853** | -0.038 | 0.110 | 0.136 |
| Tobacco | .927** | .738** | .863** | .778** | .674** | .753** | 695** | 1.000 | 0.343 | .415* | 871** | .383* | .407* | 0.350 |
| Potato | .371* | .564** | .426* | -0.073 | 0.126 | -0.062 | 0.107 | 0.343 | 1.000 | .879** | 0.321 | .984** | .916** | .749** |
| Tomato | .396* | .615** | .478** | 0.142 | 0.034 | 0.183 | 0.169 | .415* | .879** | 1.000 | 487** | .893** | .906** | .918** |
| Peas | .800** | .627** | .875** | .798** | .512** | .730** | 853** | .871** | 0.321 | .487** | 1.000 | .374* | .499** | .444* |
| Cabbage and kale | .429* | .600** | .436* | -0.017 | 0.156 | -0.011 | 0.038 | .383* | .984** | .893** | .374* | 1.000 | .937** | .762** |
| Onion | .406* | .644** | .486** | 0.054 | 0.050 | 0.055 | 0.110 | .407* | .916** | .906** | 499** | .937** | 1.000 | .831** |
| Peppers | 0.243 | .657** | 0.345 | 0.101 | -0.166 | 0.078 | 0.136 | 0.350 | .749** | .918** | .444* | .762** | .831** | 1.000 |
| Beans | .372* | .690** | .420* | 0.067 | 0.069 | 0.029 | 0.033 | .432* | .900** | .907** | .434* | .905** | .883** | .905** |
| Melons and watermelons | .561** | .600** | .534** | .389* | 0.283 | 0.293 | 0.313 | .569** | .766** | .827** | 610** | .805** | .793** | .718** |
| Cucumber | .423* | .632** | .469** | 0.060 | 0.132 | 0.114 | 0.064 | .423* | .925** | .931** | .418* | .929** | .898** | .822** |
| Garlic | 0.288 | .473** | 0.269 | -0.190 | 0.087 | -0.187 | 0.275 | 0.200 | .947** | .779** | 0.133 | .940** | .843** | .624** |
| Lucerne | .409* | .762** | .500** | 0.125 | 0.032 | 0.091 | 0.110 | .455* | .868** | .925** | 480** | .874** | .904** | .916** |
| Clover | .394* | .577** | .457* | -0.060 | 0.102 | -0.009 | 0.016 | .370* | .974** | .875** | .391* | .976** | .939** | .762** |
| Apples | .428* | .725** | .439* | 0.150 | -0.015 | 0.259 | 0.215 | .457* | .775** | .899** | 468** | .800** | .834** | .871** |
| Pears | .430* | .599** | .447* | -0.035 | 0.165 | -0.002 | 0.058 | .401* | .986** | .881** | 0.359 | .992** | .923** | .751** |
| Plums | .474** | .657** | .454* | -0.010 | 0.171 | 0.023 | 0.034 | .422* | .961** | .863** | .369* | .980** | .923** | .738** |
| Grapes | .461* | .679** | .482** | 0.079 | 0.128 | 0.050 | 0.032 | .452* | .964** | .933** | .445* | .978** | .950** | .841** |
| Strawberries | .368* | .721** | .368* | 0.213 | -0.080 | 0.188 | 0.188 | .427* | .745** | .908** | .453* | .769** | .815** | .922** |
| Raspberries | 0.049 | .551** | 0.062 | -0.064 | -.430* | 0.080 | 0.061 | 0.119 | .503** | .718** | 0.172 | .515** | .619** | .821** |
| Sour cherries | 0.333 | .725** | 0.341 | 0.136 | -0.103 | 0.150 | 0.132 | .396* | .713** | .859** | .386* | .737** | .779** | .891** |
| Peach | .844** | .550** | .798** | .466** | .712** | .464** | .410* | .776** | .641** | .547** | 697** | .686** | .595** | 0.324 |

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Source: SORS, Database and authors' calculation.

Table 3. Continued.

| Crop | Beans | Melons and watermelons | Cucumber | Garlic | Lucerne | Clover | Apples | Pears | Plums | Grapes | Strawberries | Raspberries | Sour cherries | Peach |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | .372* | .561** | .423* | 0.288 | .409* | .394* | .428* | .430* | .474** | .461* | .368* | 0.049 | 0.333 | .844** |
| Barley | .690** | .600** | .632** | .473** | .762** | .577** | .725** | .599** | .657** | .679** | .721** | .551** | .725** | .550** |
| Maize | .420* | .534** | .469** | 0.269 | .500** | .457* | .439* | .447* | .454* | .482** | .368* | 0.062 | 0.341 | .798** |
| Rapeseed | 0.067 | .389* | 0.060 | -0.190 | 0.125 | -0.060 | 0.150 | -0.035 | -0.010 | 0.079 | 0.213 | -0.064 | 0.136 | .466** |
| Sugar beet | 0.069 | 0.283 | 0.132 | 0.087 | 0.032 | 0.102 | -0.015 | 0.165 | 0.171 | 0.128 | -0.080 | -.430* | -0.103 | .712** |
| Sunflower | 0.029 | 0.293 | 0.114 | -0.187 | 0.091 | -0.009 | 0.259 | -0.002 | 0.023 | 0.050 | 0.188 | 0.080 | 0.150 | .464** |
| Soya | 0.033 | 0.313 | 0.064 | -0.275 | 0.110 | -0.016 | 0.215 | -0.058 | -0.034 | 0.032 | 0.188 | 0.061 | 0.132 | .410* |
| Tobacco | .432* | .569** | .423* | 0.200 | .455* | .370* | .457* | .401* | .422* | .452* | .427* | 0.119 | .396* | .776** |
| Potato | .900** | .766** | .925** | .947** | .868** | .974** | .775** | .986** | .961** | .964** | .745** | .503** | .713** | .641** |
| Tomato | .907** | .827** | .931** | .779** | .925** | .875** | .899** | .881** | .863** | .933** | .908** | .718** | .859** | .547** |
| Peas | .434* | .610** | .418* | 0.133 | .480** | .391* | .468** | 0.359 | .369* | .445* | .453* | 0.172 | .386* | .697** |
| Cabbage and kale | .905** | .805** | .929** | .940** | .874** | .976** | .800** | .992** | .980** | .978** | .769** | .515** | .737** | .686** |
| Onion | .883** | .793** | .898** | .843** | .904** | .939** | .834** | .923** | .923** | .950** | .815** | .619** | .779** | .595** |
| Peppers | .905** | .718** | .822** | .624** | .916** | .762** | .871** | .751** | .738** | .841** | .922** | .821** | .891** | 0.324 |
| Beans | 1.000 | .811** | .921** | .807** | .931** | .895** | .855** | .907** | .891** | .941** | .883** | .650** | .838** | .543** |
| Melons and watermelons | .811** | 1.000 | .854** | .716** | .786** | .755** | .748** | .790** | .789** | .851** | .797** | .445* | .705** | .695** |
| Cucumber | .921** | .854** | 1.000 | .859** | .930** | .915** | .885** | .927** | .909** | .942** | .850** | .656** | .827** | .619** |
| Garlic | .807** | .716** | .859** | 1.000 | .763** | .907** | .659** | .943** | .936** | .909** | .657** | .423* | .609** | .557** |
| Lucerne | .931** | .786** | .930** | .763** | 1.000 | .868** | .924** | .869** | .868** | .927** | .916** | .751** | .920** | .525** |
| Clover | .895** | .755** | .915** | .907** | .868** | 1.000 | .803** | .980** | .962** | .951** | .752** | .533** | .725** | .668** |
| Apples | .855** | .748** | .885** | .659** | .924** | .803** | 1.000 | .802** | .821** | .851** | .939** | .845** | .964** | .491** |
| Pears | .907** | .790** | .927** | .943** | .869** | .980** | .802** | 1.000 | .985** | .974** | .766** | .507** | .739** | .690** |
| Plums | .891** | .789** | .909** | .936** | .868** | .962** | .821** | .985** | 1.000 | .972** | .787** | .527** | .761** | .692** |
| Grapes | .941** | .851** | .942** | .909** | .927** | .951** | .851** | .974** | .972** | 1.000 | .854** | .590** | .810** | .657** |
| Strawberries | .883** | .797** | .850** | .657** | .916** | .752** | .939** | .766** | .787** | .854** | 1.000 | .833** | .961** | .396* |
| Raspberries | .650** | .445* | .656** | .423* | .751** | .533** | .845** | .507** | .527** | .590** | .833** | 1.000 | .867** | -0.004 |
| Sour cherries | .838** | .705** | .827** | .609** | .920** | .725** | .964** | .739** | .761** | .810** | .961** | .867** | 1.000 | .370* |
| Peach | .543** | .695** | .619** | .557** | .525** | .668** | .491** | .690** | .692** | .657** | .396* | -0.004 | .370* | 1.000 |

The simple linear correlation analysis pointed to the following results:

- ✓ There is a high positive correlation between the areas under lucerne and clover and the areas under fruit plantings;
- ✓ A strong positive correlation between wheat and tobacco areas was found (0.927**);
- ✓ For areas under maize, there was a higher degree of agreement with areas under peas (0.798**) than under soya (0.681**);
- ✓ A high positive correlation between areas under sunflower and soya (0.891**) was found;
- ✓ A significant negative correlation between areas under raspberries and sugar beets (-0.430*) was found.

## Conclusion

The results of the study show that the northern and southern regions are equally represented in the structure of the arable land and that each region has areas under the plant crops by which they are recognized. In the North of Serbia, cereals and industrial crops have been successfully cultivated, while in the South of Serbia significant areas under vegetables, fodder plants and perennial crops are distributed. This structure and the distribution of crops enable the population to have access to all food products without creating dependence on imports.

Spearman's correlation coefficient indicates the strength of the relationship between the areas of analyzed crops at the Republic level. A high positive correlation between areas under fodder and fruit plantations was found, then between areas under wheat and tobacco, as well as sunflower and soya. Also, a significant negative correlation between the areas under raspberries and sugar beets (-0.430*) was found.

**Acknowledgements**

This paper is a part of the research within the Project No. 46006: "Sustainable agriculture and rural development in the function of accomplishment of strategic goals of the Republic of Serbia within the Danube region", and the Project No. 179028: "Rural work market and rural economics of Serbia - diversification of income and decrease of rural poverty" financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia (2011–2019).

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Received: July 29, 2019
Accepted: December 24, 2019

# TENDENCIJE BILJNE PROIZVODNJE U REPUBLICI SRBIJI I NA NIVOU NSTJ 1

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R e z i m e

U radu su analizirane tendencije biljne proizvodnje u Republici Srbiji i na nivou teritorijalnih jedinica Srbija-sever i Srbija-jug (NSTJ 1), u periodu 2009–2018. godine preko indikatora zastupljenosti površina i prosečnog prinosa dvadeset osam biljnih kultura. Za obradu posmatranih indikatora korišćene su metode deskriptivne statistike kao i Spirmanov koeficijent korelacije. Podaci su ukazali da u regionu Srbija-sever dominiraju površine pod žitima, industrijskim biljem, graškom i breskvama, dok su u regionu Srbija-jug zastupljene površine pod krmnim biljem, povrtarskim kulturama (krompir, paradajz, paprika, crni luk, beli luk, pasulj, krastavac, dinje i lubenice) i višegodišnjim zasadima. Prosečni prinosi posmatranih kultura značajno se razlikuju između regiona Srbija-sever i Srbija-jug. Spirmanov koeficijent korelacije indikatora zastupljenosti površina ukazao je na visok stepen slaganja površina pod pšenicom i duvanom (0,927**), kao i površina pod lucerkom i detelinom sa površinama pod zasadima voća. Takođe, ustanovljen je i visok stepen slaganja površina pod kukuruzom i graškom (0,798**), ali i između površina pod suncokretom i sojom (0,891**).

**Ključne reči:** biljna proizvodnja, usevi, korišćeno zemljište, NSTJ 1, indikatori.

Primljeno: 29. jula 2019.
Odobreno: 24. decembra 2019.

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Journal of Agricultural Sciences
Vol. 65, No. 1, 2020
Pages 85-98

https://doi.org/10.2298/JAS2001085O
UDC: 631.151(669)
Original scientific paper

# DETERMINANTS OF FARMERS' PARTICIPATION IN FARM SETTLEMENT SCHEME IN LAGOS STATE, NIGERIA: LESSONS FOR FUTURE RURAL DEVELOPMENT PROGRAMMES

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**Abstract:** In its determination to provide food and jobs for Nigerians, and appeal to educated young men to set the pattern for farming, many state governments have re-introduced Farm Settlement Scheme (FSS)/Graduate Employment Scheme once abandoned. One major challenge leading to programme failure in Nigeria is the inability to know the influence of the factors on the participation and constraints of such programmes. This study analysed the determinants of crop farmers' participation in FSS in Lagos State with the aim of drawing some lessons for future rural development programmes. One hundred and thirty (130) farmers were sampled through two-stage sampling procedures. Data were collected with the aid of a questionnaire and were analysed using both descriptive and inferential statistics such as the logit regression model. Results show that about 67% of the respondents were male and 72% were married. The major constraining factors to participation in FSS were administrative bottlenecks, inadequate capital, and government interference. The logit regression showed that educational level, farming experience, extension contacts and security of land under FSS were the significant variables ($P<0.5$) that directly influenced the probability of participation of the farmers in FSS in Lagos State, Nigeria. Farming experience is very crucial for the survival of FSS. Therefore, it is recommended that the determinants of participation and constraints to the participation of the farmers be assessed in any rural development programme to know the necessary action against failure. The effort at increasing extension contacts about FSS will further encourage farmers to participate in FSS.

**Key words:** food shortage, farming systems, land, commercial farming operation.

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## Introduction

The problem of food shortages and insecurity is exacerbated in Nigeria because food production is probably in the hands of small scale farmers practicing mixed cropping systems and cultivating fragmented land (Fawole and Oladele, 2007). Nigeria government is re-introducing the abandoned farm settlement schemes in the western region in the 1950s (The pointer, 2015; The Hope, 2017) as the National Farm Settlement and Youth Empowerment Agency to create a mechanized system of farming and for the purpose of attaining food sufficiency (Nwabughiogu, 2017) despite the assertion that farm settlement schemes are obsolete, having typically been implemented only in Third World countries lacking the stability and resources to have permanent success.

Farm settlement is a government initiative for promoting rural development (Jaeger, 1981) by providing small farmers with resources and land for commercial farm operations, efficiency in the utilization of land resources and dignity in farming through the provision of infrastructure (Shafto, 2017). A secondary goal was to increase the standard of living among rural communities in a cost-effective manner and discourage rural-urban migration. This was modelled after the Isreali Moshavim, a co-operative, semi-collective agricultural settlement, designed as part of the Zionist state building programme where members work together to develop the land, increase the economy of the state and defend the nation (Aron, 1968, Abdulsalam, 2016). African countries have been home to the most ambitious farm settlement schemes (FSS) with some assistance of foreign aid organizations. For instance, there is Land Resettlement Scheme in Kenya. Under the scheme, three types of settlements were established namely, the high-density scheme, the low-density scheme and the yeoman scheme. The high-density scheme is the most important in terms of its largeness and coupled with the fact that it absorbs both the landless and unemployed with little or no capital or agricultural knowledge. The low-density schemes are exclusively for experienced farmers with working capital. The yeoman scheme is meant for wealthy and experienced farmers (Igbanibo, 2012). We have the Nyakashaka Resettlement Scheme in Uganda established by the Church of Uganda to provide prospects for productive farming for young school leavers that are unemployed; the Farm Settlement Scheme in Western and Eastern Nigeria which was established to attract young educated persons to take up farming and discard the negative ideas they have on farming as well as to demonstrate that by careful planning, farms can be established and operated by young educated farmers with reasonable assistance in form of advice and loans from government; the Gezira Scheme in Sudan where peasants, young school leavers and unemployed persons were settled in large-scale modern farming enterprises with a centralized management that co-ordinate the farming activities of the settlers.

In general, FSSs depend on participants voluntarily relocating, and are seen as the fastest method for developing rural areas. They serve as testing grounds for new farming methods and as a way to transform market economies. Governments implement the schemes with the hope that by infusing large amounts of capital into specific areas, surrounding areas would benefit economically.

A FSS involves the relocation of a group of people who lack capital and land resources to go into profitable farming. Farmers in the scheme are usually educated and possess enough management drive in making career. They are only given basic training in the art of cultivation and management of the mandate crops (Famoriyo, 1986). Farm settlements are stable place to live, grow crops and possibly raise animals with movement only when the soil in the area lost fertility.

The main purpose of this study was to examine, among others, factors influencing farmers' participation in farm settlement scheme (FSS) and identify constraints encountered by farmers in their willingness to participate in the FSS in the study area.

## Farm settlement schemes in Nigeria and guidelines for management of FSS in Lagos State

Farm settlement scheme was initiated by some regional governments in Nigeria and was a critical element of Western Nigeria Policy of Agricultural and Natural Resources of 1959 (Iwuchukwu and Igbokwe, 2012). The main objective of this scheme was to settle young school leavers in a specified area of land, making farming their career thereby preventing them from moving to the urban areas in search of white-collar jobs (Olatunbosun, 1964). These settled farmers were also to serve as models in good farming systems for farmers residing in nearby villages to emulate. Land was acquired by the State Government from local chieftains and native authorities. Each settler was to receive six to eight hectares of land, of which one and a half hectares were for subsistence crops. Enterprises on the settlements included cash crops and livestock products. Primary school leavers (most of them aged between 11 and 14 years) were recruited and trained in farm institutes for two to three years and eventually settled on the farms. The settler's initial contributions lay in the provision of part of the labour necessary for establishing the holdings. All the expenditure was borne by the Government, while the settlers were expected to acquire complete ownership by repayment of that component of Government's investment which included the settler's house and the establishment of his/her farm unit. The primary objectives of the FSS both in the Western and Eastern parts of Nigeria were to provide employment and income for school leavers, arrest the wave of rural migration to the towns, increase agricultural productivity, and demonstrate modern techniques of farming and to solve the land tenure problem, a major constraint to agricultural development (Ambali and

Murana, 2017). Unfortunately, the scheme went into oblivion with the few available ones in jeopardy because some of the settlers were too young and inexperienced in farming thus causing a high percentage of drop-outs among the settlers (Amalu, 1998), shortage of fund, politicking with the programme, lack of understanding of the meaning and implication of the scheme by some settlers who assumed that through their participation in the scheme they would eventually get paid job. Most settlers left the settlement, discouraged by the hard life on the settlement, the crop failures, the size of their debts and the authoritarian behaviour of the staff, a compulsory saving scheme and delays in paying the food allowance (Roider, 1968). Thirdly, the cost of establishing a viable farm settlement was too high in terms of cash and staff (Amalu, 1998).

In addition, expenses made on the scheme were incurred mainly on installation of infrastructure like construction of houses, schools, markets, roads for the settlers which did not directly bring about an increase in agricultural output by the participants as targeted (Iwuchukwu and Igbokwe, 2012). The Civil War also played a major part to the failure of the scheme. Many resources that should have been used for the scheme were diverted for military purposes thus hindering the farm settlements in meeting up their planned targets.

In Lagos State, the following guidelines are stipulated by the government in running of farm settlements in the State (Lagos State Department of Agricultural Services, 2013).

- To select applicants for the FSS, a team of experienced Senior Ministry Officials shall be set up for the purpose of conducting an interview with applicants every time the need arises.
- Any potential settler in the State should be aged between 21 and 40 years.
- In order to ensure easy understanding of directives and trainings, all settlers to be recruited should have at least the West African School Certificate (WASC) or its equivalent.
- Preference would be given to married applicants due to the likelihood of being more responsible and possible access to family labour.
- All successful applicants would be compelled to undergo 3-month training at the Government-owned training institution before being settled in the settlement and such training would be at the expense of the successful applicant.
- Each settler in the farm settlement is to be allocated a minimum of one (1) hectare of land depending on the enterprise. This size is to ensure that settlers are able to operate on a scale large enough to earn adequate income to fend for his family all-year-round.
- The one hectare should be inclusive of the area accommodating all farm structures except the settlers’ residence.

- No settler should on any account embark on the growing of permanent or cash crops.
- The settler's residential buildings are to be constructed by the Government.
- Ownership of the buildings shall on no account change from the Government to the settlers and under no circumstance shall the settlers be allowed to alter either the design or structure of the buildings.
- Renovation and maintenance of the settlers' houses, where and when necessary shall be settlers' responsibilities.
- Where there is a need for any other farm structure to be erected by the settlers, approval should be sought from the Ministry through a letter.
- Each settler is expected to spend 10 years on the settlement after which he/she will be entitled to re-apply for another 10 years' tenure subject to approval of the Lagos State Ministry of Agriculture.
- Within this period, the Ministry will assist all settlers in the area of counselling, production, access to credit facilities as well as investment. All these are aimed at ensuring that the settlers live a comfortable life after leaving the settlement.
- On attaining the age of 59 years, the settlers will be compelled to put forward the name and other information about their recommended successor to the Ministry.
- When the settler attains the age of 60 years, the recommended successor will be invited for an interview using the laid down guidelines for recruitment in the farm settlement scheme.
- Where the recommended successor falls short of the requirement, further actions as determined by the director of agricultural services in the Ministry will be taken.
- If successful, the settler is to go through the requisite training and return as a full-fledge settler now replacing his/her predecessor (that is, the original settler who recommended him/her).
- The settlement shall be cooperative in nature. This means that all settlers must be members of their settlement's Multipurpose Cooperative Society and non-compliances with this are to be penalized with eviction.

## Materials and Methods

### The study area

The study was carried out in Lagos, Nigeria. Lagos sometimes referred to as Lagos State to distinguish it from Lagos Metropolitan Area is a state located in the southwestern geopolitical zone of Nigeria with Ikeja as the capital city. The

Metropolitan area of Lagos includes: Ikeja (which is the capital of Lagos State), Agege and Mushin**.** As for the land area, Lagos State is the smallest state in Nigeria with 356,861ha of land of which 75,755 ha is wetland and 169,613ha is designated for agriculture. Out of the portion originally earmarked for agriculture, only 30% is currently cultivated (National Bureau of Statistics, 2010). The state is still the epicentre of Nigeria's economic and social development. The state contains Lagos, the nation's largest urban area with a population of 9,113,605 (NPC, 2006) and estimated to be over 21 million in 2016 by the National Population Commission of Nigeria surpassing Cairo as Africa's largest city. Lagos State is bounded to the North and the East by Ogun State. In the West, it shares boundaries with the Republic of Benin. Behind its southern borders lies the Atlantic Ocean. About 22% of its 3,577 $km^2$ are lagoons and creeks. Lagos is a port which originated on islands separated by creeks **(**Lagos State Government, 2017).

The state government's policy on agriculture hinges on enhanced food production, expanded employment opportunities and sustained growth in strategic crop production and animal husbandry. Agricultural practices in the state include animal and crop productions. Animal production includes fish farming and livestock. Crops that are produced are coconut, rice, cassava and vegetables.

Sampling procedures and sample size

Two-stage sampling procedures were used to select the respondents in the study. The sampling frame consisted of the lists of farm families in five communities that spread across Lagos State. This was obtained from the Lagos State Ministry of Agriculture (LASMA) and Lagos State Agricultural Development Authority (LASADA). In the first stage, five communities with the farm settlement were purposively used (Imota in Imota local council development area of Lagos State (formerly in Ikorodu LGA), Igboye, Araga, all in Epe Local Government Area (LGA), Ajara in Badagry LGA, and Ododunyan in Ikorodu LGA). The second stage involved the random selection of farmers proportionate to the size of the farm families in each of the selected community. In total, one hundred and thirty (20 from Imota, 26 from Igboye, 27 from Araga, 24 from Ajara, and 33 from Ododunyan in Ikorodu) farmers were selected and used for the study.

Method of data collection

Primary data were mainly used in this study, and the data were collected using a well-structured questionnaire. The information obtained from the sampled farmers included their socioeconomic characteristics such as farming experience, household size, educational status, farm size, sex, marital status among participants in the farm settlement scheme and challenges facing farmers to participate in farm settlement schemes in the study area.

Method of data analysis

Descriptive and inferential statistics were used for data analysis. The descriptive statistic was used to examine the socioeconomic characteristics and to ascertain the constraints encountered by farmers in participating in FSS, while inferential statistic used the logit regression model to determine the factors influencing farmers' decision to participate in FSS.

The logit regression model is a unit or multivariate technique which allows for estimating the probability of occurrence of an event by predicting a binary dependent outcome from a set of independent variables. This was used to determine the factors affecting farmers' participation in FSS. There are two reasons for choosing the logit model for this study instead of linear probability and probit models according to Rahman and Alamu (2003). The logit model ensures production of probability of choice within the (0, 1) range. This is an advantage over linear probability model and it is easier and more convenient to compute than the probit model. The logit model is based on the cumulative logistic probability function and it is computationally tractable. According to Gujarati and Porter (2009), it is expressed as:

$$Z_i = log\frac{(P(Y=i)}{(1-P=i)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + - - - - - - \beta_n X_n + U \quad (1)$$

Equation 1 states that the log of the odds ratio is a linear function of the Bs as well as the Xs where

$Z_i$ = the logit (log of the odds ratio). The stimulus index which ranges from minus infinity to plus infinity;

P = probability with a value ranging between zero and one and it is non-linearly related to $Z_i$. As *Pi*, the probability goes from 0 to 1, the logit *Zi* goes from $-\infty$ to $+\infty$. Although the probabilities lie between 0 and 1, the logits are unbounded (Gujarati, 2012). If $Z_{i,}$ the logit, is positive, it means that when the value of the explanatory variables (Xs) increases, the odds of participation increase, whereas if it is negative, the odds of participation decrease.

$Y_i$ = Willingness of the 'i'$^{th}$ farmer to participate in the farm settlement scheme (1 willing to participate, 0 otherwise),

$X_1$ = Sex (0 = males, 1 otherwise),

$X_2$ =Age of the farmer (years),

$X_3$ = Marital status (1 if married, 0 otherwise),

$X_4$ = Educational level of farmers (years of schooling),

$X_5$ = Farming experience (years),

$X_6$ = Extension contacts (number of visits),

$X_7$ = Parental background in agriculture (1 parent is into agriculture, 0 otherwise),

$X_8$ = Security of land under the farm settlement scheme (1 if secure, 0 otherwise),

$X_9$ = Type of crops to grow (1 for agreement to grow arable crops, 0 otherwise),

$\beta_1 - \beta_n$ = coefficients of stimulus variables,

$\beta_0$ = constant term,

$u$= error term.

## Results and Discussion

Socioeconomic characteristics of respondents

Table 1 shows the socioeconomic characteristics of the respondents. The majority (66.9%) of the farmers are males. This offers an opportunity for farmers to participate in FSS because males have more time and resources and are more independent than females in less developed nations like Nigeria. About 77.7% of them are within the age range of 30–50 years, with an average of 42.1. This age range is usually more active and can be an asset to farmers' participation in FSS although the age restriction to participation in FSS was found to be 21–40 years (Lagos State Department of Agricultural Services, 2013). Sixty-two (62%) earned an income range of ₦140,001 ₦200,000, with a mean of ₦194,832 ($618.51) per month. This income level was quite low given the high cost of input used by farmers. This may discourage farmers from participating in FSS. To improve this, there may be a need to increase the size of land allocation to the participants from 1ha to more than 5ha in order to make them at least medium-scale farmers. Most (60%) of the farmers had more than 10 years of farming experience, with an average of 14.6 years. This shows that the farmers had enough experience and knowledge which should help the farmers to participate effectively and sustain FSS compared to the early FSS that failed because the settlers were too young and inexperienced in farming causing a high percentage of drop-outs among the settlers. The minimum farm size of 1ha and maximum of 4ha with a mean value of 2.1 ha under the farm settlement scheme is too small for commercial farming within FSS.

Table 1. The distribution of socio-economic characteristics of respondents.

| Farmers characteristics | Freq. % | Farmers characteristics | Freq. % |
|---|---|---|---|
| *Sex* | | *Household size* | |
| Male | 66.9 | 1-5 | 76.2 |
| Female | 33.1 | 6-9 | 23.8 |
| *Age (year)* | | (Mean 4.8)<br>*Farming system** | |
| 30–40 | 46.2 | Livestock | 21.5 |
| 41–50 | 31.5 | Mono-cropping | 19.2 |
| 51–60 | 22.3 | Mixed cropping | 72.3 |
| (mean = 42.1yrs) | | Mixed farming | 6.2 |
| *Educational level* | | *Marital Status* | |
| No formal education | 4.6 | Single | 17.7 |
| Primary education | 9 | Married | 71.5 |
| Secondary education | 35.4 | Widow | 7.0 |
| Post-secondary education | 44.6 | Divorced | 3.8 |
| *Farming experience* | | *Farm size (ha)* | |
| <5 years | 12 | <1.0 | 57.7 |
| 5–10 | 48 | 2.0–3.0 | 23.1 |
| 11–15 | 22 | 3.1– 4.0 | 16.9 |
| >15 | 18 | >4.0 | 2.3 |
| Mean = 14.6 years | | Mean = 2.1ha<br>Minimum =1ha<br>Maximum = 4ha | |
| *Income level (in Naira/month)* | | | |
| <80,000 | | | |
| 80,001–140,000 | 11 | | |
| 140,001–200,000 | 14 | | |
| >200,000 | 62 | | |
| (mean = ₦194,832) ≈ $618.51 | 13 | | |

*Represents multiple-choice responses, $1 is equivalent to ₦315.

Awareness and participation of farmers in the farm settlement scheme

The majority of the farmers (86%) were aware of the scheme while 14% of them were not aware of the scheme as indicated in Table 2. However, out of those that were aware, only 41.1% participated in the scheme as indicated in Table 2. Thus 58.9% of the farmers did not participate in the scheme although aware of the scheme based on the guideline stipulated by the state government and other constraints (Table 3).

Table 2. The distribution of farmers according to their awareness of FSS.

| Awareness | Number of respondents | Percentage |
|---|---|---|
| Yes | 112 | 86.2 |
| No | 18 | 13.8 |
| Total | 130 | 100 |
| Participation level | | |
| Participated in FSS | 46 | 41.1 |
| No participation in FSS | 66 | 58.9 |
| Total | 112 | 100.0 |

Constraints associated with participation in farm settlements schemes

Participation in the farm settlement scheme is constrained majorly by administrative bottlenecks in the selection of participants for the scheme. For instance, apart from the interview for Lagos FSS, the potential settler must be between the ages of 21–40 years, has at least West African School Certificate (WASC) or its equivalent. Inadequate capital is another constraining factor. All successful applicants are compelled to undergo 3-month training at the government-owned training institution before being settled in the settlement at their own expense. Interference from management authority (State Ministry of Agriculture) and restriction on what the settlement should be used for are other major constraints. For instance, all settlers must be members of their settlement's Multipurpose Cooperative Society and no settler on any account is allowed to embark on the growing of permanent or cash crops. In addition, most of the respondents viewed the allocation of 1ha plot size to each settler as being too small for commercialization.

Table 3. Constraints to participation in the farm settlement scheme.

| Constraints* | Frequency | Percentage (%) | Rank |
|---|---|---|---|
| Inadequate capital | 80 | 61.5 | 2nd |
| Poor road network to the farm settlement site | 61 | 46.9 | 6th |
| Administrative bottlenecks | 105 | 80 | 1st |
| Interference from management authority | 78 | 60.0 | 3rd |
| Small farm size allocation | 64 | 49.2 | 5th |
| Regular meetings by settlers | 39 | 30.0 | 7th |
| Locations of the farm settlement | 67 | 51.3 | 4th |
| Limitations to the number of things in which the farm settlements can be put into use | 78 | 60.0 | 3rd |

*Multiple responses.

Factors affecting participation in the farm settlement scheme

The parameters of the logit regression model were estimated using the SPSS statistical package. The Chi-square statistic of 65.246 ($p < 0.1$) showed that the model gave a good fit for the analysis. The result of the logit regression in Table 4 shows that the educational level of the farmers, farming experience, extension contacts and security of land in FSS were significant variables that directly influenced their participation in the FSS at the 5% significance level in the study area. The variable such as education is positive because settlers need to be able to understand some directives and trainings that will be given in the farm settlement.

Table 4. Results of the logit regression analysis on factors affecting farmers' participation in the farm settlement scheme.

| Variables | Coefficient | Standard error | t-value | Marginal effect |
|---|---|---|---|---|
| Constant | -2.32*** | -0.8815 | 2.632 | 1.80 |
| Sex ($X_1$) | 25.145 | 196.4453 | 0.128 | 12.34 |
| Age ($X_2$) | -1.356 | 1.5658 | -0.866 | -0.70 |
| Marital status ($X_3$) | 23.737 | 17.6615 | 1.344 | 16.32 |
| Education ($X_4$) | 1.324** | 0.6477 | 2.044 | 1.40 |
| Farming experience ($X_5$) | 2.334** | 1.0396 | 2.245 | 1.21 |
| Extension contacts ($X_6$) | 3.454** | 1.5475 | 2.232 | 0.68 |
| Parental background in agriculture ($X_7$) | 1.233 | 0.8671 | 1.422 | 0.55 |
| Types of crops to grow on the site ($X_8$) | 0.152 | 10.6294 | 0.0143 | 0.14 |
| Land security in FSS ($X_9$) | 2.223** | 1.0526 | 2.112 | 0.11 |
| Log-likelihood function = | -55.248 | | | |
| Chi-square = | 65.246 | | | |

***significant at1%, ** significant at 5%.

## Conclusion

The findings of this study showed that the majority (86%) of the respondents were aware of the Farm Settlement Scheme in Lagos State, but only 41% of the respondents participated in the scheme as they were constrained/discouraged by the administrative bottlenecks in becoming a settler, inadequate capital, poor road networks and limitations to the number of things in which the farm settlements can be put into use. The result of the logit regression analysis showed that socioeconomic variables (the educational level, extension contacts, farming experience and security of land under the scheme) had a positive and significant influence on the participation of the farmers in FSS. To ensure the survival and continuity of FSS, farmers who are yet to participate need to be properly sensitized on the importance of FSS through the agricultural extension agents. Provision of good infrastructure in all the farm settlement areas will remove the constraint of poor infrastructure discouraging some farmers from participating in the FSS. Lagos and other countries interested in developing their rural areas through farm settlement schemes can borrow from the experience of the Kenyan three-level FSS models. The high-density scheme in the models is meant for the landless and unemployed with little or no capital or agricultural knowledge, the low-density schemes, exclusively for experienced farmers with working capital and the 'yeoman scheme' for the wealthy and experienced farmers. The model serves as an example of the possibility of participating in FSS (especially by the landless and unemployed youth) without capital. Education and farming experience are very crucial for participation and survival of FSS. These can be achieved through training and retraining of would-be participants and those who are participating in the scheme.

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Received: January 3, 2018
Accepted: December 20, 2019

# ODREDNICE UČEŠĆA POLJOPRIVREDNIKA U SHEMI POLJOPRIVREDNIH NASELJA U DRŽAVI LAGOS, NIGERIJA: LEKCIJE ZA BUDUĆE PROGRAME RURALNOG RAZVOJA

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R e z i m e

U svojoj odlučnosti da obezbede hranu i radna mesta za Nigerijce, i apelu mladim obrazovanim ljudima da postave obrazac za poljoprivredu, mnoge vlade su ponovo uvele Shemu poljoprivrednih naselja (SPN)/Shemu zapošljavanja diplomaca (engl. *Farm Settlement Scheme (FSS)/Graduate Employment Scheme*) koja je jednom bila napuštena. Jedan od glavnih izazova koji vode do neuspeha programa u Nigeriji je nesposobnost da se shvati uticaj faktora na učešće i ograničenja takvih programa. Ovim istraživanjem analizirane su odrednice učešća poljoprivrednika u SPN-u u Lagosu s ciljem da se izvuku neke lekcije za buduće programe ruralnog razvoja. Stotinu i trideset (130) poljoprivrednika uzorkovano je putem dvofaznih procedura uzorkovanja. Podaci su prikupljeni pomoću upitnika i analizirani korišćenjem deskriptivne inferencijalne statistike, kao što je model logističke regresije. Rezultati su pokazali da su oko 67% ispitanika bili muškarci i da je 72% u braku. Glavni ograničavajući faktori za učešće u SPN-u su administrativna uska grla, neadekvatan kapital i uplitanje vlade. Logističkom regresijom je pokazano da su nivo obrazovanja, poljoprivredno iskustvo, kontakti sa savetodavnim službama i sigurnost zemljišta u okviru SPN-a bile značajne varijable ($P<0,5$) koje su direktno uticale na verovatnoću učešća poljoprivrednika u SPN-u u Lagosu, Nigerija. Poljoprivredno iskustvo je od presudne važnosti za opstanak SPN-a. Stoga se preporučuje da se odrednice učešća i ograničenja za učešće poljoprivrednika procene u bilo kom programu ruralnog razvoja kako bi se spoznale neophodne mere protiv neuspeha. Napor ka poboljšanju kontakta sa savetodavnim službama u vezi sa SPN-om ohrabriće dalje poljoprivrednike da učestvuju u SPN-u.

**Ključne reči:** nedostatak hrane, poljoprivredni sistemi, zemlja, komercijalna poljoprivredna operacija.

Primljeno: 3. januara 2018.
Odobreno: 20. decembra 2019.

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Naslov rada treba što vernije da opiše sadržaj rada i da ima što manje reči. U interesu je autora da se u naslovu koriste reči prikladne za indeksiranje i pretraživanje. Naslov se piše velikim slovima i centrirano. Ako je rad prethodno bio izložen na nekom skupu u vidu usmenog saopštenja, pod istim ili sličnim naslovom, podatak o tome treba navesti pri dnu prve stranice, posle podataka autora za kontakt.

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Navodi se puno ime, srednje slovo i prezime svih autora, u originalnom obliku. Imena se pišu ispod naslova, malim slovima, centrirano i boldovano. Ukoliko su autori iz različitih institucija brojčanom oznakom u superskriptu, iza prezimena, označiti ustanovu u kojoj radi svaki autor. Autor za kontakt označava se zvezdicom u superskriptu, iza prezimena, komandom „insert footnote“, a njegova e-mail adresa navodi se ispod crte pri dnu prve stranice članka.

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Navodi se pun naziv i adresa ustanove u kojoj je autor zaposlen. Ispisuje se neposredno nakon imena autora, centrirano. Ukoliko su autori iz različitih institucija brojčanom oznakom u superskriptu ispred institucije označava se ustanova u kojoj je zaposlen svaki od navedenih autora.

**Sažetak**
Sažetak je kratak informativni prikaz sadržaja članka koji čitaocu omogućava da brzo i tačno odredi njegovu relevantnost. U interesu je autora da sažetak sadrži termine koji se koriste za indeksiranje i pretraživanje. Sažetak ne sme da sadrži reference. Sastavni delovi sažetka su cilj istraživanja, metode, rezultati i zaključak. Sažetak treba da ima od 200 do 250 reči. Reč „Sažetak“ piše se boldovano i uvlači jednim tabulatorom, nakon čega slede dve tačke, a zatim tekst sažetka.

**Ključne reči**
Ključne reči su termini ili fraze koje najbolje opisuju sadržaj članka za potrebe indeksiranja i pretraživanja. Broj ključnih reči može biti od 3 do 10. Navode se ispod sažetka. Naslov „Ključne reči“ piše se boldovano i uvlači jednim tabulatorom. Nakon toga slede dve tačke, a zatim nabrajanje ključnih reči malim slovima, sa tačkom na kraju. Treba izbegavati korišćenje ključnih reči koje se nalaze u naslovu rada. Ključne reči se dostavljaju na srpskom i engleskom jeziku posle sažetaka na oba jezika.

**Uvod**

Uvod treba da sadrži informacije o dosadašnjim istraživanjima po navedenom pitanju i šta se datim istraživanjem želi postići. Prilikom osvrta na literaturu, navesti autora i godinu, a autora citirati u spisku literature. Naslov „Uvod“ piše se sa prvim velikim slovom, centrirano i boldovano, nakon čega sa jednim razmakom ispod naslova sledi tekst uvoda poravnat po levoj i desnoj margini. Svaki novi pasus uvlači se jednim tabulatorom. Ova pravila važe i za sva ostala poglavlja.

**Materijal i metode**

Materijal i metode treba izložiti jasno uz objašnjenje svih primenjenih postupaka u radu. Opšte poznate metode izložiti kratko, a detaljnije ih objasniti ukoliko se odstupa od ranije objavljenih postupaka. Za radove eksperimentalnog karaktera obavezno navesti način statističke obrade podataka. U ovom poglavlju, kao i u poglavlju „Rezultati i diskusija“, po potrebi se mogu dati i određena podpoglavlja.

**Rezultati i diskusija**

U poglavlju „Rezultati i diskusija“ interpretiraju se podaci dobijeni na osnovu zapažanja i izvršenih eksperimenata. U komentaru rezultata treba se pozivati na literaturu koja se navodi na kraju rada, čime se obezbeđuje poređenje dobijenih rezultata sa dosadašnjim saznanjima u toj oblasti.

**Zaključak**

U zaključku treba ukratko navesti najznačajnije rezultate dobijene u radu. Izbegavati nabrajanje svih rezultata istraživanja sa ponavljanjem brojčanih vrednosti koje su prethodno već navedene u poglavlju „Rezultati i diskusija“. Zaključak ne sme da sadrži reference.

**Zahvalnica**

Zahvalnica treba da sadrži naziv i broj projekta, odnosno naziv programa u okviru koga je rad nastao, kao i naziv institucije koja je finansirala projekat ili program.

**Literatura**

Poglavlje „Literatura“ treba da sadrži samo radove citirane u glavnom tekstu. Rad citiran u tekstu treba da sadrži prezime autora i godinu. Ako citat obuhvata jednog autora on se navodi kao Jalikop (2010) ili (Jalikop, 2010). Kada citat obuhvata dva autora on se navodi kao Sadras i Soar (2009) ili (Sadras i Soar, 2009). Ako se u tekstu citiraju više od dva autora posle prezimena prvog autora navodi se skraćenica „et al.“, a zatim godina. Ovakav citat navodi se kao Lehrer et al. (2008) ili (Lehrer et al., 2008). Ako se za određeni problem istovremeno citira više radova onda se oni hronološki nabrajaju. Odvajanje većeg broja citiranih radova van zagrade vrši se zarezom (,) a u zagradi tačkom i zarezom (;). Ako se citiraju dva ili više rada istog autora oni moraju biti poređani prema hronološkom redu (1997, 2002, 2006, itd.). Ukoliko se određeni autor pojavljuje nekoliko puta u istoj godini, dodaju se slova (2005a, b, c, itd.). Citate ličnih komunikacija i neobjavljenih podataka treba izbegavati, osim ako je to apsolutno neophodno. Takvi citati bi trebali da se pojave samo u tekstu (npr. Brown, lična komunikacija), ali ne i u spisku referenci.

Literatura koja je citirana u tekstu navodi se u spisku referenci u originalnom obliku, po abecednom redu, bez numeracije. Ako se citira veći broj radova istog autora najpre se navode radovi kada je autor sam, a zatim kada su prisutna dva i više autora. Ako se u nekoj od ovih kategorija javlja veći broj radova, treba ih hronološki srediti po godinama (1997, 2002, 2006, itd.), a ako se u istoj godini javlja veći broj radova dodaju se slova (2005a, 2005b, 2005c, itd.). Literaturni podatak treba da sadrži: prezime autora, početno slovo imena, godinu izdanja u zagradi, naslov rada, naziv časopisa, volumen i broj stranica (prva-poslednja). Prilikom citiranja knjiga navodi se izdavač i mesto izdavanja. Redovi svake reference posle prvog reda moraju biti uvučeni. U časopisu se koristi APA - Publication Manual of the American Psychological Association citatni stil.

Primeri navođenja referenci su sledeći:

**Periodičan časopis**

Gvozdenović, S., Saftić Panković, D., Jocić, S., & Radić, V. (2009). Correlation between heterosis and genetic distance based on SSR markers in sunflower (Helianthus annuus L.). *Journal of Agricultural Sciences, 54*, 1-10.

**Knjiga**

Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

**Poglavlje u knjizi**

Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R.M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

**Zbornik**

Behera, T.K., Staub, J.E., Behera, S., Rao, A.R., & Mason, S. (2008). One cycle of phenotypic selection combined with marker assisted selection for improving yield and quality in cucumber. In M. Pitrat (Ed.), *Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae* (pp. 115-121). Avignon.

**Teza**

Singh, N.K. (1985). *The structure and genetic control of endosperm proteins in wheat and rye*. University of Adelaide.

**Izveštaj**

Ballard, J. (1998). *Some significant apple breeding stations around the world*. Selah, Washington.

**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

**Rezime**

Rezime na srpskom jeziku (za radove napisane na engleskom jeziku) ili na engleskom jeziku (za radove napisane na srpskom jeziku) navodi se na kraju rada i treba da ima od 200 do 250 reči. Ispred osnovnog teksta rezimea, navodi se naslov rada, puno ime, srednje slovo i prezime svih autora i naziv i adresa ustanove autora. Naslov „Rezime“ piše se razmaknuto i centrirano. Nakon naslova sledi jedan razmak, a zatim tekst rezimea, uvučen jednim tabulatorom. Neposredno nakon teksta rezimea, navode se ključne reči, sa tačkom na kraju. E-mail adresa autora za kontakt navodi se ispod crte, pri dnu stranice.

**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.
Mole se svi budući saradnici da rad pripreme prema datom uputstvu, kako bi olakšali rad redakcije časopisa. Ukoliko se rad ne pripremi po navedenom uputstvu neće biti prihvaćen za objavljivanje.

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CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

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**JOURNAL of Agricultural Sciences** / editor-in-chief Snežana Oljača. - [Štampano izd.]. - Vol. 44, no. 1 (1999)- . - Belgrade : University of Belgrade, Faculty of Agriculture, 1999- (Belgrade-Zemun : Faculty of Agriculture). - 24 cm

Tromesečno. - Je nastavak: Review of Research work at the Faculty of Agriculture = ISSN 0354-3498. - Drugo izdanje na drugom medijumu: Journal of Agricultural Sciences (Belgrade. Online) = ISSN 2406-0968
ISSN 1450-8109 = Journal of Agricultural Sciences (Belgrade)
COBISS.SR-ID 169380871