UDC: 63 ISSN 1450-8109

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE

Vol. 64, No. 2, 2019

Published by University of Belgrade
Faculty of Agriculture
Republic of Serbia

UDC: 63 ISSN 1450-8109

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE

Vol. 64, No. 2, 2019

Published by University of Belgrade
Faculty of Agriculture
Republic of Serbia

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

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. 64, No. 2, 2019

CONTENTS

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE
Vol. 64, No. 2, 2019

S A D R Ž A J

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 121-131
https://doi.org/10.2298/JAS1902121A
UDC: 633.15-155.9:546.17(669)
633.15-155.9:546.47(669)
633.15-182/-184(669)
Original scientific paper

RESPONSE OF MAIZE (*ZEA MAYS* L.) TO RATES OF NITROGEN AND ZINC APPLICATION IN MINNA, SOUTHERN GUINEA SAVANNA OF NIGERIA

Saheed G. Afolabi*

Department of Soil Science and Land Management, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Nigeria

Abstract: A field experiment was conducted in 2014 and 2015 cropping seasons at the Teaching and Research Farm of the Federal University of Technology, Minna to evaluate the effects of different rates of nitrogen (N) and zinc (Zn) on the growth and yield of maize. The treatments included four levels of N: 0, 60, 90 and 120 kg ha^{-1} and three levels of Zn: 0, 2.5 and 5 kg ha^{-1}. The experimental design was a 4 × 3 factorial design fitted in a randomized complete block design with three replications. The soil was relatively low in initial N content and relatively high in soil extractable Zn of 2.30 mg kg^{-1}. The main effect of N on the plant height of maize was significant ($p<0.05$) only at 8 weeks after sowing (WAS) in 2014 and 8 and 12 WAS in 2015. In 2014, the interaction effect of N and Zn on the plant height of maize was only significant ($p<0.05$) at 8 WAS in both seasons, and application of nitrogen rate of 90 kg N ha^{-1} with 5 kg Zn ha^{-1} produced the highest plant height at 8 WAS. The treatments without N produced the lowest grain and stover yields. There was a significant ($p<0.05$) response to N fertilization on grain yield in both seasons. The main effects of Zn on both stover and grain yields were only significant in 2015. The nitrogen rate of 60 kg N ha^{-1} with 2.5 kg Zn ha^{-1} was optimum for maize production in Minna, Nigeria.
Key words: zinc, nitrogen, fertilization, yield.

Introduction

Maize production in Nigeria and in sub-Saharan Africa has been found to have an increasing trend of between 2% and 3% annually (Boxall, 2000). It is one of the important staple and consumed food crops in sub-Saharan Africa (Chukwuka et al., 2014). Maize also known as corn is a crop that is cultivated widely throughout the world in a range of agro-ecological environments (IITA, 2009). Nigeria is the largest producer of maize in Africa. The north central region is the main producing area in the country.

*Corresponding author: e-mail: ooreoluwa14@gmail.com

Maize is a heavy feeder, especially in terms of nitrogen. The crop cannot perform and grow optimally without the application of some inputs in form of inorganic or organic fertilizers. There is, therefore, need for use of organic or inorganic fertilizers to restore or sustain soil fertility under intensive cropping systems in the savanna (Sanginga et al., 2003). It has been observed that nitrogen is the most deficient nutrient in the soil and it most often limits maize yield (Casky and Iwuafor, 1995). The relatively high N requirement of maize and the inherently low plant-available N in the soils of the Guinea savanna of Nigeria make N be one of the major constraints to maize production. Hence, external input of N is inevitable for maize production.

Zinc is an essential human nutrient, a cofactor for over 300 enzymes, and is found in all tissues. Zinc fertilizers increase both the yield and quality of several crops, including wheat (Hu et al., 2003; Cakmak, 2008), and rice (Liu et al., 2003). Marschner (1993) reported that using micronutrients, especially zinc, can increase grain yield of maize. Generally judicious application of Zn fertilizer helps to not only increase crop production, but also helps to enrich Zn in plant organs including grains (Jiang et al., 2008). Soils of the savanna are the most likely to be deficient in Zn due to their low soil organic matter resulting from sparse vegetation cover and annual bush burning. Organic matter has been reported to be the main reservoir of available Zn in savanna soils of Nigeria (Kparmwang et al., 1998; Mustapha and Singh, 2003). The objective of this study is to determine the effect of rates of N and Zn application and the interaction on the growth and yield of maize (*Zea mays* L.) in Minna, Southern Guinea Savanna of Nigeria.

Materials and Methods

Study site

The study site was the Teaching and Research Farm, Federal University of Technology, Minna, located at Latitude 9^o 30′ 49.8″ N; Longitude 6^o 26′ 17.5″ E, 207.8 m above sea level in the Southern Guinea Savanna of Nigeria. The climate of Minna is sub-humid, and the rainfall pattern is monomodal with the rainy season starting in March and ending in October. The monthly rainfall during the period of the study is shown in Figure 1. The soil texture was sandy loam, and pH was slightly acidic in the area.

Treatments and experimental design

The application rate included three levels of Zn 0, 2.5, 5 kg ha $^{-1}$ and four levels of N, 0, 60, 90, 120 kg N ha^{-1}. The experimental design was a 3 × 4 factorial design fitted to a randomized complete block design with three replications. Each plot size was 6 m × 4 m. The net plot was 12 m².

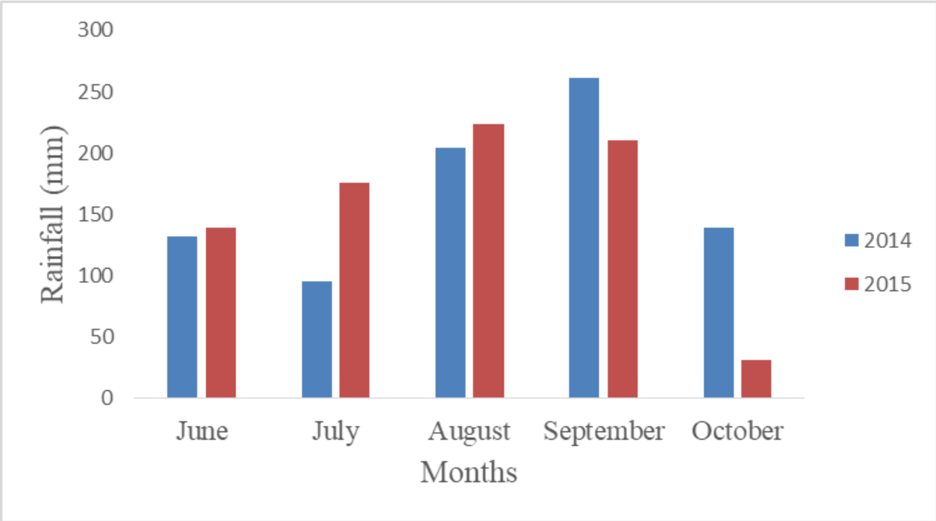


Figure 1. The rainfall distribution during the period of the study.
Source: Department of Geography, Federal University of Technology, Minna.

Agronomic practices

The field was manually cleared and ridged at 75 cm apart. The maize variety, Oba super 2 (quality protein maize), was sown (2 plants per stand) at 25 cm within the ridge. Thinning was done to one plant per stand at 2 weeks after sowing (WAS). All the plots received basal fertilizer application of 30 kg P ha^{-1} as single superphosphate, 30 kg K ha^{-1} as muriate of potash at 2 WAS. The N was applied in split application, one-third at 2 WAS while the remaining two-thirds were applied at 5 WAS. The Zn was mixed thoroughly with fertilizers. The N fertilizer was applied as urea and Zn as $ZnSO_4$ and were applied to required plots. Fertilizers were applied by side banding at about 5 cm away from the seedlings and at about 5 cm deep along the ridge. All the plots were hoe-weeded at 2 and 5 WAS and remoulding was done in place of the last weeding at 8 WAS.

Soil sampling and analysis

Surface soil (0–15 cm) samples were collected from ten points along four diagonal transects. The samples were bulked together to form a composite sample which was used to characterize the field before land preparation. The soil samples collected were air-dried, crushed gently and passed through 2-mm sieve and taken to the laboratory for physical and chemical analyses using the method described by Agbenin (1995).

Particle size distribution was determined by the Bouyoucos hydrometer method (Anderson and Ingram, 1993). Soil reaction was determined potentiometrically in 1:2.5 soil to water suspension with the glass electrode pH meter (Thomas, 1982). Organic carbon was determined by the Walkley and Black wet oxidation method (Nelson and Sommers, 1982). Exchangeable bases were determined by extraction with 1 N NH_4OAC. Potassium in the extract was determined with a flame photometer, while calcium and magnesium were determined using an atomic absorption spectrophotometer as described by Udol et al. (2009). Available phosphorous was extracted by the Bray P1 method and the P concentration in the extract was determined colorimetrically using spectrophotometer (Murphy and Riley, 1962). Total N was determined by the Kjeldahl digestion method (Bremner, 1982). Zinc was extracted using the diethylenetriamine penta-acetic acid (DTPA) extractant and Zn in solution was determined by an atomic absorption spectrophotometer.

Plant height and yield components

Plant height was observed at 4, 8 and 12 WAS by measuring from the soil level of maize plants to the tips of the tallest leaf using a meter rule. Twenty maize stands from the middle row in each of the plots were selected and the mean determined. The maize in the net plot was cut above ground level at physiological maturity, dried and weighed using a weighing balance to determine the stover yield. Maize grain yield was measured by harvesting maize ears in the net plot. The ears were air-dried, shelled and weighed.

Statistical analysis

Analysis of variance (ANOVA) was used to evaluate the treatment effects on data collected. Means separation was carried out on means of a significant difference using Duncan's multiple range test (DMRT) at the 5% level of probability. All computation was carried out by the General Linear Model (GLM) procedure of SAS (SAS, 2002).

Results and Discussion

The results of the physical and chemical properties of the soil prior to land preparation in 2014 are shown in Table 1. The soil texture was sandy loam, pH was slightly acidic, low in organic carbon, available P, total N and the extractable Zn was relatively high (Esu, 1991) and above the critical range of 0.2 to 2.0 mg kg $^{-1}$ for DTPA extractable Zn established by Sims and Johnson (1991). The value of Zn obtained (2.30 mg kg^{-1}) was similar to the critical level of 2.20 mg kg^{-1} established for some savanna soils in the pot experiment by Yusuf et al. (2005).

Table 1. Some physical and chemical properties of the soil prior to planting.

Parameters	Values
Sand (g kg^{-1})	881
Silt (g kg^{-1})	36
Clay (g kg^{-1})	83
Textural class	Sandy loam
pH in H_2O (1:2.5)	6.6
pH in $CaCl_2$ (1:2.5)	5.5
Organic carbon (g kg^{-1})	5.08
Total nitrogen (g kg^{-1})	0.06
Available P (mg kg^{-1})	9
Exchangeable bases (cmol kg^{-1})	
Ca^{2+}	2.80
Mg^{2+}	0.66
K^{+}	0.18
DTPA extractable Zn (mg kg^{-1})	2.30

The main effect of N on the growth of maize was significant only at 8 WAS in 2014 and at 8 and 12 WAS in 2015. At 8 WAS in 2014, 90 kg N ha^{-1} produced the tallest plant (181.43 cm), which was only significantly different from that of 0 kg N ha^{-1}. The application of N produced taller plants at 8 and 12 WAS in 2015 which were significantly taller than plants without N fertilization (Table 2).

Table 2. Effects of application rates of nitrogen and zinc on the plant height of maize in the 2014 and 2015 seasons.

Treatment	Plant height (cm)					
	Year					
	2014			2015		
	4WAS	8WAS	12WAS	4WAS	8WAS	12WAS
Nitrogen (N) (kg N ha^{-1})						
0	42.91a	167.08b	206.31a	57.10a	141.56b	184.00b
60	47.80a	177.59a	217.96a	59.23a	178.97a	216.22a
90	43.00a	181.43a	190.31a	57.16a	198.69a	223.68a
120	44.56a	174.44ab	212.13a	60.34a	188.01a	225.28a
SE ±	3.13	3.55	10.55	1.99	4.85	3.92
Zinc (Z) (kg Zh ha^{-1})						
0	44.75a	173.63a	193.09a	53.39b	182.96a	214.13a
2.5	45.58a	177.38a	212.05a	62.58a	162.95b	208.26a
5	46.08a	174.40a	214.89a	62.84a	171.76ab	214.50a
SE ±	2.71	3.07	9.14	1.72	4.20	3.40
Interaction						
N*Z	NS	*	NS	NS	NS	*

Means for the same column and factor followed by the same letter are not significantly different at the 5% level of probability. * Significant at the 5% level of probability. NS – Not significant.

The main effect of Zn fertilization on the height of maize was only significant at the early growth stage of maize in 2015. The application of Zn produced significantly taller plants than those without Zn application at 4 WAS in 2015, but at 8 WAS, plants without Zn produced the tallest plant with a height of 182.96 cm, which differed significantly only from the treatment with 2.5 kg Zn ha^{-1}.

The interaction effect of N and Zn on the growth of maize plants was only significant at 8 WAS in both seasons. The application of the 5kg Zn ha^{-1} and 90kg N ha^{-1} fertilization produced the tallest maize plants at 8 WAS in 2014 (Table 3). Plants with the shortest height of 159.3 cm were obtained with the application of 5 kg Zn ha^{-1} and 120 kg N ha^{-1} which was not significantly different from those of 0 kg Zn ha^{-1} at 0 kg N ha^{-1} and 60 kg N ha^{-1}. In 2015, the application of N produced tall maize plants and Zn fertilization produced the shortest plant with a height of 128.67 cm at 8 WAS in 2015 (Table 4).

Table 3. The interaction effect of nitrogen and zinc on plant height at 8 weeks after sowing in 2014.

Treatment	Zinc (kg Zn ha^{-1})		
	0	2.5	5
Nitrogen (kg N ha^{-1})			
0	159.5e	171.3d	180.6bcd
60	169.5de	185.5abc	171.0d
90	172.4d	188.1ab	193.1a
120	176.0cd	175.6cd	159.3e
SE ±		3.07	

Means in the column or row followed by the same letters are not significantly different at the 5% level of probability.

Table 4. The interaction effect of nitrogen and zinc on plant height at 8 weeks after sowing in 2015.

Treatment	Zinc (kg Zn ha^{-1})		
	0	2.5	5
Nitrogen (kg N ha^{-1})			
0	154.67cd	128.67e	141.33de
60	195.00ab	149.33de	192.57ab
90	194.77ab	17450ab	175.80abc
120	187.40ab	199.30a	177.33abc
SE ±		8.40	

Means in the column or row followed by the same letters are not significantly different at the 5% level of probability.

Nitrogen application increased the growth of maize plants. This increase might be due to the positive effect of N on plant growth (Hani et al., 2006). Several reports had earlier attributed a significant increase in the development of vegetative plant parts and dry matter accumulation to N fertilizer application as N is an important constituent of chlorophyll, amino acid and nucleic acid (Anjorin, 2013). The improvement in plant growth also corroborated the findings of Cox et al. (1993) and Sumi and Ketayama (2000), who have reported that N promotes higher leaf area development and reduced rate of senescence. Similarly, Onasanya et al. (2009) attributed an increase in the growth of the maize plant to N fertilizer application.

The main effects of N and Zn on the yields of maize in 2014 and 2015 seasons are shown in Table 5. The main effects of N and Zn on the stover yield of maize were significant in both seasons. The treatment without N produced the lowest yield which was significantly different from that of treatments with only 60 kg N ha^{-1} in 2014 and from those with N in 2015. There was a response to N with 0 kg N ha^{-1} recording significantly lower yield compared to others in both years.

The main effects of Zn on both stover and grain yields were only significant in the 2015 season. There was a response to Zn fertilization by the grain and stover yields with the 0 kg Zn ha^{-1} treatment providing the least stover and grain yields of 4778 and 3479 kg ha^{-1} respectively which were significantly different from 2.5 and 5kg Zn ha^{-1}. The interaction effects of both N and Zn on stover and grain yields were not significant in both years.

Table 5. The effects of nitrogen and zinc on the yields of maize in the 2014 and 2015 seasons.

Treatment	Year			
	2014		2015	
	Stover yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Grain yield (kg ha^{-1})
Nitrogen (N) (kg N ha^{-1})				
0	5274b	3052b	4256b	3089b
60	5919a	4366a	6317a	5644a
90	5800ab	4447a	6178a	5480a
120	5712ab	4587a	6372a	5945a
SE ±	185	188	198	445
Zinc (Z) (kg Zh ha^{-1})				
0	5602a	3937a	4778b	3479b
2.5	5738a	4292a	5965a	5275a
5	5690a	4110a	6349a	6115a
SE ±	160	163	190	386
Interaction				
N*Z	NS	NS	NS	NS

Means for the same column and factor followed by the same letter are not significantly different at the 5% level of probability. NS – Not significant.

There was clear evidence that N nutrition was a major constraint to maize production. Application of N fertilization produced the highest yield irrespective of the rate. A similar response to inorganic N fertilizer had been reported in the same area by Adeboye et al. (2009) who reported 90 kg N ha^{-1} to be optimum for maize in Minna. Lawal et al. (2015) reported an increased grain yield of maize with nitrogen application. Sajedi et al. (2009) reported that N has been found as a key input for achieving the highest yield of maize in the savanna agroecological zones. There was no response to Zn by yields of maize in 2014. This might be a result of relatively high extractable Zn in the soil.

The application of Zn fertilizer judiciously has been reported to increase crop production as well as enrich the Zn content in plant organs including grains (Sudhalakshini et al., 2007). Hossain et al. (2008) and Afolabi et al. (2016) observed that the soil application of Zn resulted in an increase in the grain yields of maize. Esmaeili et al. (2016) attributed the increased maize yield to the foliar application of Zn. Abunyewa and Mercer-Quarshie (2004) also observed an increase in the maize grain yield due to the application of 5 kg Zn ha^{-1} to the soil.

Conclusion

The results of this study show that adequate N fertilization enhanced the growth and yield of maize plants in both seasons. In addition, the nitrogen rate of 60 kg ha^{-1} and the zinc rate of 2.5 kg ha^{-1} were optimum for maize grain yield in Minna, southern Guinea savanna of Nigeria.

References

Abunyewa, A.A., & Mercer-Quarshie, H. (2004). Response of maize to magnesium and zinc application in the semi arid zone of West Africa. *Asian Journal of Plant Science*, *3,* 1-5.

Anderson, J.M., & Ingram, J.S. (1993). *Tropical soil biology and fertility.* A handbook of methods. Information press Eynsham.

Adeboye, M.K.A., Osunde, A.O., Tsado, P.A., Odofin, J.A., Bala, A., & Adeyemi, R.A. (2009). Response of maize grain yields to rates and split application of nitrogen and NPK combinations in the southern Guinea savanna of Nigeria. *Journal of Agriculture and Agricultural Technology, 2* (1), 108-118.

Afolabi, S.G., Adeboye, M.K.A., Lawal, B.A., Daniya, E., & Chinma, C.E. (2016). Effects of Methods and Time of Application of Zinc on Maize (*Zea mays L.*) Productivity in the Southern Guinea Savanna of Nigeria. *Nigerian Journal of Soil and Environmental Research*, *14*, 92-99.

Agbenin, J.O. (1995). *Laboratory Manual for Soil and Plant Analysis.* (Selected Methods and Data Analysis). Published by the author. 140pp.

Anjorin, F.B. (2013). Comparative growth and grain yield response of five maize varieties to nitrogen fertilizer application. *Greener Journal of Agricultural Sciences*, *3* (12), 801-808.

Boxall, R.A. (2000). Post-harvest technology of quality protein maize: storage and processing, choosing the right technology, fruit report. Chatham U.K. NRI.

Bremner, J.M. (1982). Inorganic nitrogen. In page A. L, Miller, R. H and Keeney, D. R. (eds). Methods of soil analysis. Part II 2nd edition. *America Society of Agronomy*. Madison Wiscosin.

Cakmak, I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil*, *302*, 1-17.

Carsky, R.J., & Iwuafor, E.N.O. (1995). Contribution of soil fertility research and maintenance to improved maize and productivity in sub-Saharan Africa. In: Drechsel, P., Olaleye, A., Adeoti, A., Thiombiano, L., Barry, B. and Vohland, K. Adoption driver and constraints of resource conservation technologies in sub-Sacharan Africa. proceedings of Regional Maize workshop, held on 29 may-2june 1995 at IITA Cotonou, Benin Republic.

Chukwuka, K.S., Ogunsumi, I.A., Obiakara, M.C., Ojo, O.M., & Uka, U.N. (2014). Effects of decaying leaf litter and inorganic fertilizer on growth and development of maize (*Zea mays L*). *Journal of Agricultural Sciences, 59* (2), 117-127.

Cox, W.J., Kalonoge, S., Cherney. D.J.R., & Raid, W.S. (1993). Growth yield and quality of forage maize under different nitrogen management practices. *Agronomy Journal, 85*, 341-347.

Esmaeili, M., Ayoub, H. & Gholipour, M. (2016). Response of maize to foliar application of zinc and azotobacter inoculation under different levels of urea fertilizer. *Journal of Agricultural Sciences, 61* (2), 151-162.

Esu, I.E. (1991). Detailed soil survey of NIHORT Farm at Bunkure, Kano State, Nigeria. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Hani, A.E., Muna, A.H., & Eltom, E.A. (2006). The Effect of Nitrogen and Phosphorus Fertilization on Growth, Yield and Quality of Forage Maize (*Zea mays* L.). *Journal of Agronomy, 5*, 515-518.

Hossain, M.A., Jahiruddin, M., Islam, M.R., & Mian, M.H. (2008). The requirement of zinc for improvement of crop yield and mineral nutrition in the maize-mungbean-rice system. *Plant and Soil, 306*, 13-22.

Hu, Y.X., Qu, C.G., & Yu, J.N. (2003). Zinc and iron fertilizers effects on wheat output. *Chinese germplasm*, *2*, 25-28.

IITA, (2009). *Maize crop production.* Manual series. International institute for Tropical Agricultural, Ibadan, Nigeria.

Jiang, W., Struik, P.C., Kevlin, H.V. Zhao, M., Jin, L.N., & Stomph, T.J. (2008). Does increased zinc uptake enhance grain zinc mass concentration in rice? *Annals of applied biology*, *153*, 135-147.

Kparmwang, T., Esu, I.E., & Chude, V.O. (1998). Available and total forms of copper and zinc in basaltic soils of the Nigerian savanna. *Communication in soil and plant Analysis, 29*, (15/16), 2215-2216.

Lawal, B.A, Adeboye, M.K.A., Usman, A., Afolabi, S.G., & Adekanmbi, A.A. (2015). Rotation effect of *Aeschynomene histrix* on soil carbon and nitrogen and maize grain yield at Minna in the southern Guinea savanna of Nigeria. *Journal of Agriculture and Agricultural Technology, 6* (1), 1-9.

Liu , J., Li, K., Xu, J., Liang, J., Lu, X., Yang, J., & Zhu, Q. (2003). Interaction of candium and five mineral nutrients for uptake and accumulation in different rice cultivars and genotypes. *Field Crops Resources, 83* (3), 271-281.

Marschner, H. (1993). Zinc in soils and plants, Robson A.D. (ed). Kluwer Academic Publishers, Drodrcht, The Netherlands, pp 59-78.

Murphy, J., & Riley, J.P. (1962). A modified single solution method for the determination of phosphorous in natural water. *Analytical Chimica* ACTA, *27*, 31-36.

Mustapha, S., & Singh, B.R. (2003). Available zinc, copper, iron and manganese status of the basement complex rock derived Ultisols in Bauchi State, Nigeria: A case study. *Nigerian Journal of Soil Research, 4*, 35-40.

Nelson, D.W., & Sommers, L.S. (1982). Total carbon, organic carbon and organic matter. In Page, A.L. et al., Agronomy Monogram 9 (2nd edition). P. 403-430. ASA and SSSA. Madison, Wisconsin.

Ojanuga, A.G. (2006). *Agroecological Zones of Nigeria Manual*. FAO/NSPFS, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

Onasanya, R.O., Aiyelari, O.P., Onasanya, A., Oikeh, S., Nwilene, F.E., & Oyelakin, O.O. (2009). Growth and Yield Response of Maize (Zea mays L.) to Different Rates of Nitrogen and Phosphorus Fertilizers in Southern Nigeria. *World Journal of Agricultural Science, 5* (4), 400-407.

Sajedi, N.A., Ardakani, M.R., Naderi, A., Madani, H., Mashhadi, A., & Boojar, M. (2009). Response of maize to nutrients foliar application under water deficit stress condition. *American Journal of Agriculture and Biological Science, 4* (3), 242-248.

Sanginga, N., Dashiell, K., Diels, J., Valauwe, B., Lyasse, O., Carsky, R.J., & Ortiz, R. (2003). Sustainable resource management coupled with resilient germplasm to provide new intensive cereal-grain legume-livestcok systems in the dry savanna. *Agriculture Ecosystems and Environment, 100,* 305-314.

SAS (2002). SAS user`s guide; statistical Cary N.C. Statistical Analysis System Institute Inc.

Sims, J.T., & Johnson, G.V. (1991). Micronutrients Soil Tests. Second Edition. In Mortvedt, J.J., Cox, F.R., Shirman, L.M., Welch, R.M. (Eds). Micronutrients in Agriculure. Soil Science Society of America Inc., Madison, Wisconsin, USA.

Sudhalakshini, C., Krishnasamy, R., & Rajarajan, R. (2007). Influence of zinc deficiency in shoot / root dry weight ratio of rice genotypes. *Research Journal of Agriculture and Biological Sciences, 3*, 295-298.

Sumi. A., & Ketayama, T.C. (2000). Effect of nitrogen fertilizer application and solar on the growth response of sorghum seedling to soil moisture. *Crop Science, 69*, 513-519.

Thomas, G.W. (1982). Exchangeable cations method of soil analysis. Part II *Agronomy Monograph* 9. 3rd edition of ASA and SSSA, Madison Wisconsin.

Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.O., & Esu, I.E. (2009). *Manual of soil, plant and water analysis,* Sibon books LTD, flat 15, blk. 6, fourth avenue Festac, Lagos.

Yusuf, A.A., Abdu, N., Chude, V.O., Yusuf, H.A., & Pam, S.G. (2005). Response of maize (*Zea mays* L.) to zinc fertilization in relation to mehlich extractable zinc in northern Nigeria. *Nigerian Journal of Soil Research, 6,* 32-41.

Received: November 20, 2017
Accepted: April 16, 2019

ODGOVOR KUKURUZA (*ZEA MAYS* L.) NA DOZE PRIMENE AZOTA I CINKA U MINI, JUŽNOGVINEJSKA SAVANA U NIGERIJI

Saheed G. Afolabi*

Odsek za nauku o zemljištu i upravljanje zemljištem, Fakultet za poljoprivredu i poljoprivrednu tehnologiju, Federalni tehnološki univerzitet, Mina, Nigerija

R e z i m e

Poljski ogled sproveden je tokom 2014. i 2015. godine na nastavno-istraživačkom gazdinstvu Federalnog tehnološkog univerzitata u Mini kako bi se procenili uticaji različitih doza azota (N) i cinka (Zn) na rast i prinos kukuruza. Tretmani su obuhvatali četiri doze azota: 0, 60, 90 i 120 kg ha^{-1} i tri doze cinka: 0, 2,5 i 5 kg ha^{-1}. Ogled je postavljen kao 4 × 3 faktorijalni dizajn po slučajnom potpunom blok dizajnu u tri ponavljanja. Početni sadržaj azota u zemljištu bio je relativno nizak, dok je pristupačni cink od 2,30 mg kg^{-1} u zemljištu bio relativno visok. Glavni uticaj azota na visinu biljke kukuruza bio je značajan (p<0,05) samo 8 nedelja posle setve (engl. *WAS – weeks after sowing*) u 2014. i 8 i 12 nedelja posle setve u 2015. godini. Uticaj interakcije azota i cinka na visinu biljke kukuruza bio je samo značajan (p<0,05) tokom 2014. godine 8 nedelja posle setve tokom obe godine, a primena doze azota od 90 kg N ha^{-1} sa 5 kg Zn ha^{-1} proizvela je najveću visinu biljke. Tretmani bez korišćenja azota proizveli su najniži prinos zrna i kukuruzovine. Značajan (p<0,05) odgovor na đubrenje azotom zabeležen je kod prinosa zrna u obe godine. Glavni uticaji cinka, kako na prinos kukuruzovine tako i na prinos zrna, bili su samo značajni u 2015. godini. Doza azota od 60 kg N ha^{-1} sa 2,5 kg Zn ha^{-1} optimalna je za proizvodnju kukuruza u Mini u Nigeriji.

Ključne reči: cink, azot, đubrenje, prinos.

Primljeno: 20. novembra 2017.
Odobreno: 16. aprila 2019.

*Autor za kontakt: e-mail: ooreoluwa14@gmail.com

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 133-145

https://doi.org/10.2298/JAS1902133A
UDC: 633.15-154.3:631.559(55)
636.2.085.52:633.15(55)
Original scientific paper

THE EFFECTS OF SEED PRIMING, PLANTING DATE AND DENSITY ON THE SILAGE YIELD OF CORN (*ZEA MAYS* L.) IN SUMMER DELAYED SOWING

Farshid Alipour-Abookheili[1], Hamid-Reza Mobasser[2], Morteza Siavoshi[3*] and Farshid Golmaei[2]

[1]Department of Agronomy, Science and Research Branch,
Islamic Azad University, Tehran, Iran
[2]Department of Agronomy, Qaemshahr Branch,
Islamic Azad University, Qaemshahr, Iran
[3]Department of Agricultural Science, Payame Noor University, Iran

Abstract: To determine the effects of seed priming, date and density of planting on the silage yield of corn (Ks.c_{704} cultivar) in summer delayed planting, an experiment was carried out as a split-split plot in a randomized complete block design with four replications in 2015 and 2016. Treatments were examined including two planting dates (July 27 and August 13) as main plots, two planting densities (7 and 9 plants per m^2) as sub plots and four levels of seed priming (without priming, distilled water, 0.5% KNO_3 and 10% $PEG_{(8000)}$) as sub-sub plots. The results showed maximum of the speed and percentage of seedling emergence at the first year. The number of days decreased from planting date until 8- and 12-leaf stages in seed priming by the distilled water method. The silage yield decreased (26.69%) with the late planting (13 August), but the speed of seedling emergence increased. The planting density (9 plants/m^2) yielded the highest percentage of lignin, speed of seedling emergence, plant height and silage yield. The highest ratio of the ear fresh weight to the total silage weight was obtained by the late planting date (13 August) and seed priming with the PEG method. The maximum value of the silage yield (45,566.41 kg/ha) was produced by the early planting date (27 July) and higher planting density (9 plants/m^2). Thus, to increase seedling emergence speed and to obtain maximum silage yield, early planting date (27 July), higher planting density (9 plants/m^2) and seed priming by the distilled water method are recommended.

Key words: plant density, seed priming, corn silage yield, sowing date.

[*]Corresponding author: e-mail: Morteza_siavoshi@yahoo.com

Introduction

Corn is the most important plant among cereal crops after wheat and rice. Corn cultivation has been increased because of increasing animal husbandry industry in the last several years in Iran (Fathi, 2005). Corn is one of the most suitable crop plants to produce green manure and silage due to high starch in seed and yield of this plant (Khodabandeh, 2000). Corn silage herb will be provided under general conditions easily until energy and herb sustainable quality are obtained (Curran and Posch, 2000). Germination and seedling emergence speed is one of the most important and effective factors to attain maximum yield for most crop plants (Subedy and Ma, 2005). The seed priming treatment can increase the ability and speed of seed germination (Farooq et al., 2006). The seed priming treatment will lower the time between dates until seedling emergence. Because of that, the seeds germinate equally, which will improve the quantity and quality of the yield of the plant (Basra et al., 2004). Murungu et al. (2003) have found that seed priming treatment increased seedling emergence percentage and seedling growth of corn as compared with the witness treatment (without priming). The most common methods for seed priming are hydro-priming and osmo-priming. Regarding the osmo-priming method, seeds will be settled into solutions with low osmotic potential, which include chemical materials such as poly-ethylene glycol (PEG), menthol and chemical fertilizers like urea (Ashraf and Foolad, 2001). Seeds will be also soaked into water and will be dried before completing seed germination within the hydro-priming method. Determination of the suitable planting date for crop plants is important to use the potential of the variety, soil and climate of each region (Estakhr and Dehqanpour, 2010). Sadeghi and Bahrani (2002) have examined the effect of three planting dates (24 April, 4 and 14 May) on silage corn and the maximum silage yield was obtained (13388 kg/ha) on 24 April. The maximum yield for every plant can be influenced by determining the suitable plant density regarding the climate conditions and variety properties (Nourmohammadi et al., 2001). Viddicombe and Thelen (2002) have reported that high planting density (90,000 plants/ha) increased grain yield as compared with low planting density (560,000 plants/ha). The most appropriate plant density to achieve maximum yield (79,040 plant/ha) was also suggested by Bean and Gerik (2000). Therefore, this research was conducted to find out the effect of pre-sowing seed treatment (seed priming), date and density of planting on the corn silage yield of $S.C_{704}$ variety in the summer delayed sowing.

Materials and methods

This experiment was carried out as a split-split plot design in a randomized complete block design with four replications in the Agricultural Research Center of

Qarakheyl - Qaemshahr, Mazandaran province during the two agronomic years (2015 and 2016). The soil of the test site had a clay loamy texture with acidity of 7.1, organic matter of 1.8% and electrical conductivity of 0.26 dS/m. Meteorological data for two years are shown in Table 1. Planting date has been chosen as a main plot at two levels (27 July and 13 August) and planting density has been selected as a sub-plot at two levels (7 and 9 plants per m^2). Seed priming has been also preferred as a sub-sub plot at four levels: control (without priming), distilled water, 0.5% potassium nitrate $(KNO_3)_2$- and 10% poly-ethylene glycol (PEG_{8000}). The experimental field was divided into 4 blocks equal to the number of replications of each treatment combination. Each block was divided into 2 main plots, which were divided further into 2 sub-plots. Each sub-plot was then divided into 4 sub-sub plots. Thus, there were 16 sub-sub plots in each block, which was repeated 4 times. The main plot, sub-plot and sub-sub plot treatments were arranged completely randomly.

Table 1. Meteorological data for two years.

Variable	Minimum temp. (°C)		Maximum temp. (°C)		Evaporation (mm)		Precipitation (mm)	
Year	2015	2016	2015	2016	2015	2016	2015	2016
May	14.6	14	21.8	24	82.0	75	25.3	32
June	20.1	19	28.5	30	159.8	110	1.5	28
July	22.6	22	31.1	34	171.5	128	48.1	9.2
August	23.9	25	32.2	34	170.2	156	31.2	12.2
September	19.9	18	27.8	28	100.7	121	98.6	48
October	15.7	15	25.2	18	78.4	85	143.2	82
November	8.4	14	15.7	16	42.4	82	144.9	95

The plot size was 4.5*6 m^2. In the row, seven plants were cultivated at each plot and the distance between each row was 75 cm. As for seed priming, the selected seeds were combined with provided solution of earlier mentioned materials, during 24 hours. After that, settled seeds were dried under natural conditions and then were cultivated in plots. Regarding the soil test, the amount of chemical fertilizers was added to the soil and other agronomic operations such as care and harvesting operations were done. The measured traits within this research included: phonological traits such as the number of days from the planting date until 8 leaves and the number of days from the planting date until 12 leaves, speed and percentage of seedling emergence and percentage of lignin, plant height, silage yield, yield components such as plant fresh weight, silage yield per surface unit, the ratio of the leaf fresh weight to total silage weight, the ratio of the stem fresh weight to total silage weight and the ratio of the ear fresh weight to total silage weight. To determine the speed of seedling emergence, the number of emerged coleoptiles from soil surface was counted daily per plot and measured for two weeks. To determine the percentage of seedling emergence, all of emerged coleoptiles were counted 14 days after germination. To determine the rest of morphological characteristics like yield and yield components, 10 plants were chosen per plot and then were measured with general methods. Data were analyzed by using the analysis of variance technique (ANOVA) and Microsoft-MSTAT-C, and the mean differences were calculated by Duncan's test at the probability levels of 5 and 1% (Gomez and Gomez, 1984).

Results and Discussion

Phonological traits

Results showed that the numbers of days from the planting date until 8- and 12-leaf stages were significantly influenced by planting date, year, and interaction effects of experimental factors (Table 2). Table 3 shows that the minimum numbers of days from the planting date until 8- and 12-leaf stages were obtained by early planting (27 July) in the 1st year (2015). Decreasing the numbers of days from the planting date until 8- and 12-leaf stages was caused by increasing the crop growth rate (CGR) and decreasing the plant growth period (PGP) from planting until harvesting stages. This result is not in agreement with earlier works (Khan et al., 2002; Rafiee and Asgharpour, 2009) that have shown that late planting decreased the number of days from the planting date until different stages of growth like 12-leaf and maturing stages. Seed priming with distilled water decreased the number of days from the planting date until 8- and 12-leaf stages (Table 3). Wahid et al. (2008) also found that the seed priming treatment of sunflower decreased the number of days from the planting date until 50% germination and increased the speed of seedling emergence. Plant height was significantly affected by year, planting date and density (Table 2). Table 3 shows that the maximum plant height (241.48, 245.91 and 241.23 cm) for early planting date (27 July) and planting density (9 plants/m^2) were measured in the first year (2015). Rafiee and Asgharpour (2009), Feyzbakhsh and et al. (2010), Atrashi (1998), Hassan (2000) and Bazi et al. (2005) have found the same results.

Germination traits

The percentage of seedling emergence was significantly influenced by year and seed priming and their interaction with planting density (Table 2). This result is in agreement with the earlier study by Abotalebian et al. (2006). Table 3 statistically shows that the percentage of seedling emergence was higher in the 1st year (88.92%) than in the 2nd year (83.22%). The maximum generation (87.80%)

was obtained in control treatment (Table 3) and a higher interaction effect was found between control treatment and planting density (90.97%) (Table 4).

Table 2. Square means of quantitative, qualitative and phonological characteristics of the silage corn S.C$_{704}$ in summer delayed planting.

Source of variation	df	Seedling emergence	Speed of seedling emergence	Planting until the 8-leaf stage	Planting until the 12-leaf stage	Plant height
Replication	3	187.36**	78.52**	44.52**	66.08**	197.95 ^{ns}
Year	1	1040.42**	314.002**	153.13**	56.008*	2150.45**
Error (a)	3	28.18	20.39	29.94	24.78	166.82
Planting date	1	32.11^{ns}	425.23**	488.28**	249.40**	9311.86**
Year*Planting date	1	3.51^{ns}	946.89**	148.78**	4.25 ^{ns}	304.27 ^{ns}
Error (b)	6	36.50	10.96	39.41	47.70	1186.32
Planting density	1	99.60^{ns}	1511.95**	4.50^{ns}	14.67 ^{ns}	1897.67**
Density*Year	1	2.37^{ns}	211.58^{ns}	0.13^{ns}	5.56 ^{ns}	346.03 ^{ns}
Density*Date	1	37.79^{ns}	0.15^{ns}	3.78 ^{ns}	1.53 ^{ns}	583.75 ^{ns}
Year*Density*Date	1	64.48^{ns}	41.93*	0.03 ^{ns}	9.39 ^{ns}	0.11 ^{ns}
Error (c)	12	61.60	18.89	27.55	26.47 ^{ns}	379.71 ^{ns}
Seed priming	3	86.42*	29.56*	20.17 ^{ns}	22.78 ^{ns}	60.97 ^{ns}
Year*Priming	3	8.08^{ns}	3.86^{ns}	1.46 ^{ns}	2.43 ^{ns}	37.18 ^{ns}
Date*Priming	3	60.09^{ns}	9.71^{ns}	0.36 ^{ns}	8.94 ^{ns}	48.11 ^{ns}
Year*Date*Priming	3	5.67^{ns}	0.36^{ns}	6.20 ^{ns}	10.08 ^{ns}	53.68 ^{ns}
Density*Priming	3	88.62*	14.58^{ns}	12.50 ^{ns}	5.95 ^{ns}	37.84 ^{ns}
Year*Density*Priming	3	16.35^{ns}	12.75^{ns}	5.46 ^{ns}	4.74 ^{ns}	176.72 ^{ns}
Date*Density*Priming	3	1.23^{ns}	1.55^{ns}	4.36 ^{ns}	14.008 ^{ns}	47.83 ^{ns}
Year*Date*Density*Priming	3	7.26^{ns}	4.58^{ns}	1.28 ^{ns}	5.54 ^{ns}	133.33 ^{ns}
Error (abc)	72	29.68	7.53	7.92	9.72	233.34
CV%	-	6.33	11.44	6.81	5.35	6.44

ns, * and **; Non-significant, significant and very signicifant at the levels of 5% and 1% respectively.

Seed priming with the PEG method increased the speed and percentage of seedling emergence and the ratio of ear fresh weight to total silage weight and that is why seed priming can be suggested for other crops under dry climate conditions where the speed and percentage of seedling emergence are the most important objectives of all researchers and farmers. As Table 2 shows, planting date and year and their interaction effects influenced the speed of seedling emergence. Feyzbakhsh et al. (2010) have also found that planting date affects the speed of seedling emergence and the rest of plant phonological stages. Planting density and seed priming also significantly affected the speed of seedling emergence. The seed priming treatment of wheat increased the speed and percentage of seedling emergence, tillering and earlier flowering (Harris et al., 2001). Moradi and Yonesi (2009) have shown that seed hydro-priming increased the speed of seedling emergence. Table 3 shows that the speed of seedling emergence was higher in the 1st year (25.56 seeds/day) than in the 2nd year (22.43 seeds/day). The maximum speed of seedling emergence was also related to planting density of 9 plants/m^2 (27.43 seeds/day). The maximum value of the speed of seedling emergence (30.85 seeds/day) was also attained by interaction effects between year (1st year), early planting date (27 July) and planting density (9 plants/m^2) (Table 4).

Table 3. Mean comparison of simple effects of experimental treatments on quantitative, qualitative and phonological characteristics of the silage corn S.C704 in the summer delayed planting.

Treatment		Seedling emergence percentage (%)	Seedling emergence speed (per day)	No. of days from planting until the 8-leaf stage	No. of days from planting until the 12-leaf stage	Plant height (cm)
Year	2015	88.92	25.56	40.22	57.65	241.48
	2016	83.22	22.43	42.41	58.97	233.28
Planting date	27 July	86.57	22.17	39.36	56.92	245.91
	13 August	85.57	25.82	43.27	59.71	228.85
Planting density	7 plants/m^2	85.19	20.56	41.50	58.65	233.53
	9 plants/m^2	86.96	27.43	41.13	57.97	241.23
Seed priming	Control	87.80	24.61	41.00	57.99	236.74
	Distilled water	86.99	24.98	40.88	57.48	238.52
	PEG	84.12	22.92	42.50	59.47	235.74
	KNO_3	85.39	23.48	40.88	58.31	238.53

The given means per each column with the same letters do not show significant differences statistically ($p<0.05$).

Table 4. Mean comparison of interaction effects of Year*Date, Density*Priming and Year*Date*Density on some agronomic properties of the silage corn $S.C_{704}$ in the summer delayed planting.

Treatment		No. of days from planting until the 8-leaf stage	Treatment		Seedling emergence (%)	Treatment		Seedling emergence speed (per day)
Year *Date			Density *Priming	7 plants/m^2*control	84.62b	Year *Date *Density	2010*27J*7 plants	22.07b
				7 plants/m^2*distilled water	87.38ab		2010*27J*9 plants	30.85a
	2015*27J	37.19b		7 plants/m^2*PEG	84.43b		2010*13A*7 plants	21.36b
	2015*13A	43.25a		7 plants/m^2*KNO_3	84.34b		2010*13A*9 plants	27.98a
	2016*27J	41.53a		9 plants/m^2*control	90.97a		2011*27J*7 plants	15.47c
	2016*13A	43.28a		9 plants/m^2*distilled water	86.60b		2011*27J*9 plants	20.31b
				9 plants/m^2*PEG	83.81b		2011*13A*7 plants	23.34b
				9 plants/m^2*KNO_3	86.84b		2011*13A*9 plants	30.61a

The given means per each column with the same letters do not show significant differences statistically ($p<0.05$).

Silage corn yield

The fresh weight of plant was significantly influenced by year and planting date (Table 5). Regarding Table 6, the maximum plant fresh weight was observed in the 2nd year (546.79 g) in earlier sowing time (588.02 g). Year, planting date, their interaction effect and planting density significantly increased the ratio of leaf fresh weight and the part of stem fresh weight to total silage weight. Year, planting date, their interaction effect and planting density also significantly increased the ratio of ear fresh weight to total silage weight (Table 5).

Table 5. Square means of quantitative, qualitative and phenological characteristics of the silage corn $S.C_{704}$ in the summer delayed planting.

Source of variation	df	Plant fresh weight	Ratio of leaf fresh weight to total silage weight	Ratio of stem fresh weight to total silage weight	Ratio of ear fresh weight to total silage weight	Silage yield	Lignin
Replication	3	4072.26 ns	2.54**	3.25 ns	8.04 ns	8448561 ns	0.41ns
Year	1	19128.21*	201.73**	280.73**	2.89 ns	506100 ns	0.84ns
Error (a)	3	6828.61	4.59	2.07	6.10	78188705	1.82
Planting date	1	635732.7**	331.24**	52.86**	119.85**	3815981661**	2.39ns
Year*Planting date	1	946.37 ns	281.74**	705.28**	95.81**	47974037 ns	1.15ns
Error (b)	6	8394.94	3.70	7.40	14.85	54823722	2.82
Planting density	1	4196.20 ns	2.55**	28.03**	47.53**	929491333**	23.47**
Density*Year	1	2367.75 ns	0.56 ns	0.93 ns	2.94 ns	35608540 ns	0.98ns
Density*Date	1	10112.55 ns	0.01 ns	2.29 ns	1.81 ns	492247906**	1.44ns
Year*Density*Date	1	905.68 ns	0.22 ns	15.48*	12.39 ns	64535891 ns	1.62ns
Error (c)	12	8246.43 ns	0.18 ns	3.84 ns	3.80 ns	24109684 ns	2.43
Seed priming	3	736.08 ns	0.18 ns	20.06**	19.18*	22845777 ns	4.19*
Year*Priming	3	401.85 ns	1.82**	3.53 ns	2.38 ns	12430952 ns	4.88*
Date*Priming	3	7295.72 ns	0.51 ns	11.42*	16.009*	19882147 ns	1.12ns
Year*Date*Priming	3	421.24 ns	0.43 ns	3.91 ns	6.36 ns	6565978 ns	0.91ns
Density*Priming	3	6919.38 ns	0.12 ns	1.51 ns	1.37 ns	10876537 ns	2.82ns
Year*Density*Priming	3	1039.28 ns	0.23 ns	1.92 ns	2.85 ns	5075946 ns	1.11ns
Date*Density*Priming	3	6256.09 ns	0.66*	4.54 ns	5.74 ns	16733197 ns	1.95ns
Year*Date*Density*Priming	3	7424.81 ns	1.05 ns	5.61 ns	10.17 ns	15976794 ns	2.51ns
Error (abc)	72	3093.48	0.47	3.60	4.80	31269511	1.49
CV%		10.40	6.59	4.08	5.10	15.77	5.79

ns, * and **: Non-significant, significant and very significant at the levels of 5% and 1%, respectively.

The results showed that the maximum ratios of leaf fresh weight and stem fresh weight to total silage weight were attained in the 1st year (0.12) and in the 2nd year (0.48) respectively. The maximum values of the ratio of leaf fresh weight to total silage weight were attained by the early planting (0.12) and the maximum values of the ratio of stem fresh weight to total silage weight were also reached by the late planting (0.47) (Table 6). The present studied variety (S.C 704) of the corn plant includes the maximum leaf fresh weight because of its late maturity (Heydar-Qolinezhad Kenari et al., 2003; Genter and Camper, 1973). Planting density (9 plants/m^2) increased the ratio of leaf fresh weight and stem fresh weight to total silage weight at the maximum values of 0.11 and 0.47, respectively. The maximum ratio of ear fresh weight to total silage weight was related to the late planting date (0.44) and planting density of 7 plants/m^2 (0.44) (Table 6). Seed priming significantly affected the ratio of stem fresh weight and ear fresh weight to total silage weight. The interaction effect between seed priming and planting date also affected these characteristics significantly (Table 5). Treatments of the interaction effect between the late planting (13 August) and seed priming attained the maximum ratio of stem fresh weight to total silage weight (0.49) with the KNO_3. This result was obtained on wheat and barley plants by Karaki (1998). The maximum ratio of ear fresh weight to total silage weight (0.46) was achieved by the interaction effect between the late planting date (13 August) and seed priming with the PEG method (Table 8). The maximum ratio of ear fresh weight to total silage weight (0.45) was also obtained by the interaction effect between the late planting date (13 August) and year (1st year) (Table 7). Planting date, plant density and their interaction effect increased silage yield significantly (Table 5).

Table 6. Mean comparison of simple effects of experimental treatments on quantitative, qualitative and phonological characteristics of the silage corn $S.C_{704}$ in the summer delayed planting.

Treatment		Lignin (%)	Plant fresh weight (gr)	Ratio of leaf fresh weight to total silage weight	Ratio of stem fresh weight to total silage weight	Ratio of ear fresh weight to total silage weight	Silage yield (kg/ha)
Year	2015	21.20	522.34	0.12	0.45	0.43	35513.4
	2016	21.04	546.79	0.09	0.48	0.43	35387.7
Planting date	27 July	21.26	588.02	0.12	0.46	0.42	40910.6
	13 August	20.99	481.11	0.09	0.47	0.44	29990.5
Planting density	7 plants/m^2	20.69	528.84	0.10	0.46	0.44	32755.8
	9 plants/m^2	21.55	540.29	0.11	0.47	0.42	38145.3
Seed priming	Control	20.94	537.06	0.11	0.47	0.43	35366
	Distilled water	21.05	534.22	0.10	0.47	0.43	35800
	PEG	21.65	527.99	0.11	0.46	0.44	34324
	KNO_3	20.85	538.98	0.10	0.47	0.42	36313

The given means per each column with the same letters do not show significant differences statistically ($p<0.05$).

The results of the present study are in agreement with Darby and Laure (2002), Mokhtarpour et al. (2008), Feyzbakhsh et al. (2010), Fallah and Tedin (2009) and Dehqanpour and Vahdat (1996). The maximum silage yield was related to the early planting date (40,910.6 kg/ha) and the planting density of 9 plants/m^2 (38,145.3 kg/ha) (Table 6) and their interaction effects (45,566.41 kg/ha) (Table 7). Fayazbakhsh et al. (2010) found that the highest silage yield (85,000 plants/ha) was achieved with the planting density of 8.5 plants/m^2. In addition, the maximum silage yield was obtained with the planting density of 13 plants /m^2 (Zamaniyan and Najafi, 2002). The results showed that the planting density affected the percentage of lignin significantly at the level of 1%. Seed priming and its interaction effect with year also affected the percentage of lignin at the level of 5% (Table 5). As can be seen in Table 6, the maximum lignin percentage was definite with the planting density of 9 plants/m^2 (21.55%) and seed priming with the PEG method (21.65%). The highest lignin (21.70) was also found by the interaction effect between year (2nd year) and the seed priming PEG method (Table 8).

Table 7. Mean comparison of interaction effects of Year*Date and Date*Density on some agronomic properties of the silage corn S.C$_{704}$ in the summer delayed planting.

Treatment		Ratio of leaf fresh weight to total silage weight	Ratio of ear fresh weight to total silage weight	Treatment		Silage yield (kg/ha)
Year* Date	2015*27J	0.12a	0.41b	Date* Density	27J*7 plants/m^2	36254.84b
	2015*13A	0.12a	0.45a		27J*9 plants/m^2	45566.41a
	2016*27J	0.12a	0.43b		13A*7 plants/m^2	29256.79c
	2016*13A	0.06b	0.43b		13A*9 plants/m^2	30724.19c

The given means per each column with the same letters do not show significant differences statistically ($p<0.05$).

Table 8. Mean comparison of interaction effects of Year*Priming and Date*Priming and Density*Priming on some agronomic properties of the silage corn S.C$_{704}$ in the summer delayed planting.

Treatment		Ratio of leaf fresh weight to total silage weight	Lignin (%)	Treatment		Ratio of stem fresh weight to total silage weight	Ratio of ear fresh weight to total silage weight
Year * Priming	2015*control	0.12a	20.61bc	Date * Priming	27J.*control	0.46bc	0.42c
	2015*distilled water	0.12a	21.16abc		27J.*distilled water	0.46bc	0.42c
	2015*PEG	0.12a	21.60a		27J.*PEG	0.45c	0.43bc
	2015*KNO_3	0.11b	21.45ab		27J.*KNO_3	0.46bc	0.42c
	2016*control	0.09d	21.27ab		13A.*control	0.47b	0.44b
	2016*distilled water	0.09d	20.95abc		13A.*distilled wate	0.47b	0.44b
	2016*PEG	0.09d	21.70a		13A.*PEG	0.46bc	0.46a
	2016*KNO_3	0.10c	20.25c		13A.*KNO_3	0.49a	0.42c

The given means per each column with the same letters do not show significant differences statistically ($p<0.05$).

Conclusion

Regarding the obtained results of the present study, the maximum percentage of lignin, seedling emergence, plant height, the ratio of leaf fresh weight to total silage weight, the ratio of ear fresh weight to total silage weight and silage yield were attained in the 1st year (2015) which raised crop growth rate (CGR). The maximum values of the percentage of lignin and the percentage of seedling emergence, plant height, plant fresh weight, the ratio of leaf fresh weight to total silage weight and silage yield were achieved with the early planting date (17 July). The number of days with earlier sowing time (17 July) from the planting date until the 8- and 12-leaf stages decreased in the 1st year (2015). On the other hand, the crop plant rate increased, but the plant growth period decreased from planting until harvesting. All of the maximum phonological and morphological characteristics of the corn plant were also attained with the planting density of 9 plants/m^2, except for the ratio of ear fresh weight to total silage weight. The results show that many treatments showed high values in the 1st year (2015) and with the early planting date (17 July) and the planting density of 9 plants/m^2. Therefore, it can be concluded that the early planting date (17 July) and the planting density of 9 plants/m^2 are the best treatment to obtain the maximum silage yield of the corn S.C$_{704}$ variety in the summer delayed sowing. Thus, this treatment can be recommended for farmers who work in moderate climate conditions.

References

Abotalebian, M., Sharifzadeh, F., Jahansoz, R., Ahmadi, A., & Naqavi, M.R. (2006). The effect of Osmo-priming on speed, percentage and basic temperature of germination seedling basic index of 6 varieties of wheat seed. *Scientific Journal, 5* (1), 67-82. (In persian).

Ashraf, M., & Rauf, H. (2001). Inducing salt tolerate in maize (*Zea Mays* L.) Thought seed priming with chloride salts: growth and ion transport at early growth stages. *Acta-Physioliga Plantarum, 23*, 407- 414.

Atrashi, M. (1998). Effects of sowing date and plant density on yield and seed physical and chemical propertie of different hybrids corn. Abstracts *Proceedings of 5th Iranian Congress of Crop Production and Plant Breeding.* 368 pp. (In Persian with English Summary).

Basra, S.M.A., Ashraf, M., Iqbal, N., Khaliq, A., & Ahmad, R. (2004). Physiological and biochemical aspects of pre-sowing heat stress on cottonseed. *Seed Science and Technology, 32*, 765-774.

Bazi, M.T., Nemati, N., Mokhtarpour, H., & Mosavat, S.A. (2005). Effects of tiller removal and plant density on ear yield and forage of sweet corn. Azad Uni. of varamin. (In persian).

Bean, B., & Gerik, T. (2000). Evaluating corn row spacing and plant density in Texas Panhandle, Texas A. and M. University system. *Soil and Crop Science,* 2000-2028.

Curran, B., & Posch, J. (2000). Agronomic management of silage for yield and quality: silage cutting height. Crop in sights, 10 (2). Pioneer Hi-bred International. INC.

Darby, H.M., & Lauer, J.G. (2002). Planting date and hybrid influence on corn forage yield and quality. *Agronomy Journal, 94*, 281-289.

Dehqanpour, Z., & Vahdat, A. (1996). Examination the effect of planting date and density on silage yield of corn S.C 704 in Mash-had. *Agricultural Research Journal Seed* and seedling providing and breeding Institute, *120*, 24-30. (In persian).

Estakhr, A., & Dehqanpour, Z. (2010). Determination of the suitable planting date for new varieties of early maturity of corn at the 2nd cultivation in moderate climate of Fars provience. *Seed and Plant, 2* (2), 169-191. (In persian).

Fallah, S., & Tedin, A. (2009). The effect of plant density and Nitrogen amount on yield and Nitrate and Protein uptake of silage corn. *Electronic Journal of crop plant production, 2* (1), 105-121. (In persian).

Farooq, M., Basra, S.M.A., Tabassum, R. & Afzal, I. (2006). Enhancing the performance of direct seeded fine rice by seed priming. *Plant Production Science, 9*, 446- 456.

Fathi, Q. (2005). Examination of the effect of planting pattern and density on light depreciation coefficient, radiate assimilation on grain yield of corn S.C.402. *Agricultural Sciences and Natural Resources, Special Crop,* 131-143. (In persian).

Feyzbakhsh, M., Mokhtarpour, H., Mosavat, S.A., Mohajer, M., & Shahi, Q. (2010). The effect of planting date and plant density on yield and some morphological traits of maize cv SC704. *Electronic Journal of crop plant production, 3* (1), 217-224. (In persian).

Genter, C., & Camper, H. (1973). Component plant part development in maize as effected by hybrids and population density. *Agronomy Journal, 65*, 669-671.

Gomez, K.A., & Gomez, A.A. (1984). *Statistical procedures for agricultural research* (2nd Edn.). John Wiley sons, New York, Chichester, Bribane, Toronto, Singapore.

Harris, D., Reghuwanshi, B.S., Gangwar, J.S., & Singh, S.C. (2001). Participatory evalution by farmer sofon-farm seed priming in wheat in India, Nepal and Pakistan. *Experimantal Agriculture, 37,* 403-415.

Hassan, A.A. (2000). Effect of plant population density on yield and yield components of eight Egyptian maize hybrids. *Bulletin of Fac. Of Agric. Univ. of Cairo, 51* (1), 1-16.

Heydar-Qolinezhad, Kenari, M., Qadimzadeh, M., & Fayazmoghadam, A. (2003). The effect of planting density on herb quality of hybrid varieties of corn according to agronomic properties. *Iranian Journal of Agricultural Sciences 34* (2), 417-425. (In persian).

Karaki, G.N. (1998). Response of wheat and barley during germination to seed osmo priming at different water potential. *Journal of Agronomy and Crop Science, 181* (4), 229-235.

Khan, N., Qasim, M., Ahmed, F., Khan, R., Khanzada, A., & Khan, B. (2002). Effects of sowing date on yield of maize under Agro climatic condition of Kaghan Valley. *Asian Journal of plant Sciences, 1* (2), 140-147.

Khodabandeh, N. (2000). *Cereals cultivation*. Published by Sepehr, Tehran Uni. P. 537. (In persian).

Mokhtarpour, H., Mosavat, S.A., Feyzbakhsh, M.T., & Saberi, A. (2008). Effect of sowing date and plant density on ear yield of sweet corn in summer sowing. *Electronic Journal of crop plant production, 1*, 101-113.

Moradi, A., & Younesi, O. (2009). Effect of Osmo and hydro-priming on seed parameters of grain sorghum. *Australian Journal of Basic Applied Sciences, 3*, 1696-1700.

Murungu, F.S., Nyamugafata, P., Chiduza, C., Clark, L.J., & Whalley, W.R. (2003). Effects of seed priming aggregate size and soil matric potential on emergence of cotton (*Gossypium hirsutum* L.) and maize (*Zea mays* L.). *Soil and Tillage Research, 74*, 161-168.

Nourmohammadi, Gh., Siyadat, A., & Kashani, A. (2001). *Cereals Cultivation*. 1st Volume. 3rd Edition. Published by Chamran Uni. P. 445. (In persian).

Rafiee, M., & M. Asgharpour, R. (2009). Examination of the effect of planting date and density on the morphological characteristics and yield components of corn S.C 604 in Shirvan. *Quarterly of dynamic agricultural, 6* (1), 23-34. (In persian).

Sadeghi, H., & Bahrani, M.J. (2002). Effects of plant density and nitrogen rates on yield and yield components of corn (*Zea mays* L.). *Iran Journal of Crop Sciences, 3*, 403-412.

Subedi, K.D., & Ma, B.L. (2005). Seed priming does not improve corn Yield in a humid temperate environment. *Agronomy Journal, 97*, 211-218.
Viddicombe, W.D. & Thelen, K. D. (2002). Row width and plant density effects on corn grain production in the Northern Corn Belt. *Agronomy Journal, 94*, 1020-1023.
Wahid, A., A. Noreen., S.M.A. Basra., Gelani, S., & Farooq, M. (2008). Priming induced metabolic changes in sunflower (*Helianthus annuus*) achenes improve germination and seedling growth. Botanical Studies, 49, 343-350.
Zamanian, M., & Najafi, A. (2002). Assessment of row spacing and plant density effect on silage yield and morphological characters of corn (S.C.704). *Seed and Plant Journal of Agricultural Research 23*, 200-214.

Received: August 18, 2018
Accepted: April 18, 2019

UTICAJI POTAPANJA SEMENA, DATUMA SETVE I GUSTINE NA PRINOS SILAŽE KUKURUZA (*ZEA MAYS* L.) U LETNJOJ ODLOŽENOJ SETVI

Farshid Alipour-Abookheili[1], Hamid-Reza Mobasser[2], Morteza Siavoshi[3*] i Farshid Golmaei[2]

[1]Odsek za agronomiju, Ogranak za nauku i istraživanje,
Islamski slobodni univerzitet, Teheran, Iran
[2]Odsek za agronomiju, Ogranak u Kaemšahru,
Islamski slobodni univerzitet, Kaemšahr, Iran
[3]Odsek za poljoprivredne nauke, Univerzitet Pajame Nur, Iran

R e z i m e

Kako bi se utvrdili uticaji potapanja semena, datuma i gustine setve na prinos silaže kukuruza (sorta Ks.c$_{704}$) kod letnje odložene setve, sproveden je eksperiment potpodeljenih parcela u potpuno slučajnom blok dizajnu sa četiri ponavljanja u 2015. i 2016. godini. Tretmani su ispitivani uključujući dva datuma setve (27. jul i 13. avgust) kao glavne parcele, dve gustine setve (7 i 9 biljaka po m^2) kao potparcele i četiri nivoa potapanja semena (bez potapanja, destilovana voda, 0,5% KNO_3 i 10% PEG$_{(8000)}$). Rezultati su pokazali maksimalnu brzinu i procenat nicanja klijanaca u prvoj godini. Broj dana se smanjivao od datuma setve do faza sa 8 i 12 listova kod potapanja semena uz pomoć metode sa destilovanom vodom. Prinos silaže se smanjio (26,69%) u kasnoj setvi (13. avgust), ali se brzina nicanja klijanaca povećala. Gustinom setve (9 biljaka/m^2) postignut je najveći procenat lignina, brzina nicanja klijanaca, visina biljke i prinos silaže. Najveći odnos sveže mase klipa i ukupne mase silaže dobijen je pri kasnom datumu setve (13. avgust) i potapanjem semena PEG metodom. Maksimalna vrednost prinosa silaže (45.566,41 kg/ha) dobijena je pri ranom datumu setve (27. jul) i većoj gustini setve (9 biljaka/m^2). Kako bi se stoga povećala brzina nicanja klijanaca i postigao maksimalni prinos silaže, preporučuju se rani datum setve (27. jul), veća gustina setve (9 biljaka/m^2) i potapanje semena metodom sa destilovanom vodom.

Ključne reči: gustina biljaka, potapanje semena, prinos silaže kukuruza, datum setve.

Primljeno: 18. avgusta 2018.
Odobreno: 18. aprila 2019.

*Autor za kontakt: e-mail: Morteza_siavoshi@yahoo.com

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 147-163

https://doi.org/10.2298/JAS1902147A
UDC: 635-155.9:582.661.21
631.41:631.559
Original scientific paper

EFFECTS OF ARBUSCULAR MYCORRHIZA FUNGI, ORGANIC FERTILIZER AND DIFFERENT MOISTURE REGIMES ON SOIL PROPERTIES AND YIELD OF *AMARANTHUS CRUENTUS*

Adebisi E. Adekanmbi and Moses B. Adewole*

Institute of Ecology and Environmental Studies,
Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract: A pot experiment was conducted to assess the influence of two arbuscular mycorrhiza (AM) fungi and organic fertilizer (OF) on the growth and yield of *Amaranthus cruentus* under varying soil moisture regimes. This was done with a view to providing information on the crop adaptation to drought conditions and to also sustaining soil nutrient balance for increased crop yields. The experiment consisted of 36 treatments (*Glomus clarum*, *Glomus deserticola* and no AM), organic fertilizer made from market wastes at different rates (0, 5 and 10 t ha^{-1}) and varied water regimes (25, 50, 75 and 100% field capacity [FC]). Each of the treatments was replicated thrice. The treatment combination, 10 t ha^{-1} OF and *G. clarum* produced the highest fresh vegetative yield of 48.82 t ha^{-1} which was not significantly ($p > 0.05$) different from only 45.78 t ha^{-1} fresh yield obtained with 5 t ha^{-1} OF and *G. clarum* when water levels were compared. The repeated experiment with only water addition gave lower and comparable yields of *A. cruentus*. We concluded that the addition of *G. clarum* in combination with 5 t ha^{-1} of organic fertilizer to soil optimally improved the growth and yield of *A. cruentus* in water stress conditions.

Key words: arbuscular mycorrhiza fungi, organic fertilizer, water stress, *Amaranthus cruentus*, market wastes.

Introduction

Crops and soil nutrition are intrinsically linked because the soil houses and provides nutrients for crops, and as a result, soil nutrient decline could lead to low quality and quantity in crop production (Murrell et al., 2015). In addition to this, there are other abiotic stresses like drought and salinity that cause one third of global agricultural losses (Vandenberghe et al., 2017). Some soil nutrient deficiencies have indirectly enhanced human activities to impact negatively on the soil ecosystem through variable cultural farm operations and agricultural

*Corresponding author: e-mail: mbadewole@gmail.com

intensification on crop lands; drought and other abiotic stresses are results of the global climate change issues (Armada et al. 2016; Salehi et al. 2016). Despite the intensified efforts to improve soil nutrient deficiency, drought is not only a problem in itself, but it also inhibits such efforts because nutrient solubility plays a significant role in their absorption by plants (Afshar et al., 2014). Although the application of inorganic fertilizers to soil enhanced soil fertility, they could also lead to loss of soil biodiversity, increased soil acidity and soil degradation, and eventually fail to increase crop yield in the long run (Chemura, 2014; Joshi et al. 2014). Sustainable soil management approaches are, therefore, necessary for a food secured population, and they also involve preserving the natural resources in the air, soil and water environments (Murrell et al., 2015).

Organic inputs are known to be a soil management strategy which plays a pertinent role in climate-smart agriculture. They are able to help soil retain moisture better and thus help alleviate moisture stress (Chemura, 2014). Also, noteworthy is their apparent role in improving soil fertility (Okonji et al., 2018), while carbon sequestration in these inputs has favorable implications for climate change (Aguilera et al., 2013; Lehtinen et al., 2014), and all these culminate in improved agricultural yield. The use of organic inputs to soils is gaining popularity because a lot of organic input sources are from degradable wastes and their use can result in waste management (Aguilera et al., 2013). Another benefit of organic fertilizers in soils is that they provide plants with a good ratio of micro minerals in addition to macro minerals (Murrell et al., 2015).

In crop production, Borie et al. (2010) have suggested that arbuscular mycorrhiza (AM) fungi incorporation into agri-business is an appropriate biotechnology alternative for food security and forest ecosystem sustainability. The AM fungi are symbiotic organisms that help plant nutrient mechanisms by facilitating their nutrient uptake and improving their tolerance to drought and other environmental issues (Eulenstein et al., 2017). The AM fungi are reported to improve plant growth in water stress conditions (Armada et al., 2016), with established controlled and field experiments conducted over a wide range of crops. These AM fungi have also been termed biofertilizers because of their role in facilitating the availability, uptake and absorption of nutrients in plants (Cyril et al., 2014). It is a function of the available nutrients in the soil since the fungi do not provide the nutrients (Medina and Azcon, 2010; Murrell et al. 2015) either to long-duration or short-duration crops such as vegetables.

Vegetables are food crops which are a major repository of vitamins, minerals and antioxidants (Ajiboye et al., 2014). Cultivation of vegetables has been challenging in recent times, in terms of farm input and soil productivity, among others (Agneessens et al., 2014; Widowati and De Neve, 2016), which has resulted in the poor yield and quality of crops. *Amaranthus* is an annual vegetable with several species which are often consumed as food, and as ornamental plants

(Zhigila et al., 2014). In Nigeria, it is commonly called ‘tete’ among the Yorubas, ‘green’ among the Igbos, and ‘aleho’ among the Hausas (Mshelmbula et al., 2017; Towolawi et al., 2017) and it is a good source of vitamins and dietary minerals (Cyril et al., 2014). This study therefore assessed the influence of two arbuscular mycorrhiza fungi (*Glomus clarum*, *Glomus deserticola*) and organic fertilizer (OF) on the growth and yield of *Amaranthus cruentus* under varying soil moisture regimes.

Materials and methods

Experimental location, design used and agronomic practices employed

The experiment was conducted in the greenhouse of the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. Viable spores of AM fungi, namely: *Glomus clarum* and *Glomus deserticola*, obtained from the Department of Agronomy, University of Ibadan, Ibadan, Nigeria were propagated using the *Zea mays* plant for a period of three months. During the propagation period, maize plants were watered regularly and chopped leaves of *Gliricidia sepium* were used to nourish the previously sterilized sandy soil used on a weekly basis. At three months, water was withdrawn from maize plants to allow for multiplication of fungi spores for two weeks. The organic fertilizer made from market wastes was procured from a waste recycling firm in a local market in Ibadan, Nigeria. Viable seeds of *Amaranthus cruentus* were obtained from the National Horticultural Research Institute, Jericho, Ibadan, Nigeria.

Surface soil sample was collected from an infertile land, sieved and sterilized and three kilograms of the sterilized soil were filled into each of the polythene pots. The experiment consisted of 36 treatments, namely: ([10 g *G. clarum*, 10 g *G. deserticola* and no AM fungi], organic fertilizer at different rates [0, 5 and 10 t ha^{-1}], varied water regimes [25, 50, 75] and 100% field capacity [FC]). Each of the treatments was replicated thrice and factorially arranged in a completely randomized design to give a total of 108 pots. Treatments were applied at sowing and plants in each pot were thinned to two stands at two weeks after sowing (WAS). The pots were maintained weed-free throughout the experimental period and they were watered appropriately.

Collection of data on growth performance commenced at 3 WAS and continued weekly thereafter until 6 WAS. Growth parameters assessed included plant height, number of leaves, stem girth and leaf area. Fresh biomass yield per pot was determined immediately after harvest using a weighing balance. The plants were then oven-dried at 70°C to constant weight using a binder FED 400 model to determine the dry biomass yield. There was a repeated experiment immediately after the harvest of the first set of the vegetable crop to test for residual effects of

AM fungi and organic fertilizer, but with only different water regimes as treatment addition.

Propagation of arbuscular mycorrhiza fungi

Soil inocula containing viable spores of AM fungi, namely *G. clarum* and *G. deserticola* were obtained from the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. Fifty grams of each inoculum were weighed into 10 kg of sterilized coarse sand, and two seeds of maize (*Zea mays*) sown into the pots. The plants were regularly watered and chopped leaves of *Gliricidia sepium* were used to nourish the soil weekly. Three months after sowing, water was withdrawn to allow for multiplication of fungi spores. Two weeks after, maize shoots were cut and soil air-dried.

Extraction and counting of arbuscular mycorrhiza fungi spores

Pre- and post-planting of extraction and counting of AM fungi spores were determined using the wet sieving and decanting method of Habte and Osorio (2001). One hundred grams of air-dried soil were taken from the sterilized bulk soil sample and the AM treatment pots, and each was thoroughly mixed. Each was soaked for 30 minutes with 250 ml of distilled water in a beaker. Each sample was thereafter made with distilled water to 1000 ml suspension and agitated for 30 minutes to dislodge the fungal spores from the soil. The soil suspension was decanted over a stack of sieves (250, 75 and 53 µm) arranged in descending order of their sizes. Thereafter, materials left in the last two sieves (75 and 53 µm) were collected, suspended in 40% sucrose solution and centrifuged at 3000 rpm for 5 minutes. The spores were later examined and counted under a dissecting microscope.

Laboratory analyses

Pre-cropped soil and organic fertilizer (OF) samples were analysed for their properties using standard methods of Page et al. (1982). Soil pH was determined in 1:1 soil/water using a pH meter; total N of the soil and OF were determined using the macro-Kjedahl method, available P of the soil and OF were determined using the Bray P1 method, and organic C of the soil and OF were determined using the Walkley-Black wet oxidation method. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) of the soil and OF were extracted using 1 M ammonium acetate and their concentrations were read using the spectrophotometric method. The summation of the exchangeable bases, $Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}$, gave cation exchange capacity (CEC) of the soil.

Statistical analyses

Data on the yield of *A. cruentus* were subjected to analysis of variance and their means were separated using the Duncan's multiple range test using SAS 9.2 statistical software at $p < 0.05$. Data on the growth parameters were plotted using GraphPad Prism 5.0 software at $p < 0.05$.

Results and Discussion

Mycorrhizal spore count

Total spore counts of AM fungi: *Glomus clarum* and *Glomus deserticola* were 114.17 ± 35.12 and 58.44 ± 17.44 per 100 g of soil, respectively. Okon and Solomon (2014) earlier obtained AM fungi spore count range of 18–112 per 100 g of soil from varieties of crops they worked on.

Soil properties

The physical and chemical properties of the soil and organic fertilizer used in the experiment are presented in Table 1. The soil was of sandy loam texture with sand, silt and clay proportions 692.00, 154.00 and 154.00 g kg^{-1} respectively.

Table 1. Pre-cropped soil and organic fertilizer properties.

Parameter	Value/Soil	Organic fertilizer
pH (1:1 soil/water)	6.70	-
Organic carbon (g kg^{-1})	0.77	76.70
N (g kg^{-1})	0.07	3.01
C:N	-	25.48
Available P (mg kg^{-1})	17.11	12.53
Exchangeable acidity (cmol kg^{-1})	0.10	-
Exchangeable basicity (cmol kg^{-1})	12.16	140.92
Ca^{2+}	9.46	24.40
Mg^{2+}	0.91	3.51
K^{+}	1.11	40.11
Na^{+}	0.68	72.91
Clay (g kg^{-1})	154.0	-
Silt (g kg^{-1})	154.0	-
Sand (g kg^{-1})	692.0	-
Textural class	Sandy loam	

The soil was slightly acidic with soil pH of 6.70. Organic carbon and total N in the soil were 0.77 and 0.07 g kg^{-1} respectively. The organic fertilizer had organic C content of 79.26 g kg^{-1} and total N of 6.97 g kg^{-1}, giving a C:N ratio of 11:1; an attribute that the organic fertilizer used has potential to decompose fast for enhanced soil fertility. The C:N ratio is a critical factor in the decomposition of organic material. The lower the C:N ratio the faster will be its rate of decomposition and nitrogen release in crop husbandry (Ge et al., 2013).

Soil water plays a significant role in organic matter decomposition, mineralization and nutrient availability during crop production. From 75% FC water regime, soil properties, particularly total N, organic C and CEC were significantly increased compared to when soil moisture regimes were much lower (Table 2). However, Rana et al. (2017) observed no significant influence of water regimes on soil organic carbon, a contrary report from our own. Variations from different studies could be attributed to differences in soil properties, chemistry of water used for wetting and water use efficiency by different crop species.

Table 2. Effects of water regimes, organic fertilizer and AMF on properties of soil.

Treatment	pH in H_2O	Organic carbon ($g\ kg^{-1}$)	Total nitrogen ($g\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)	Cation exchange capacity ($cmol\ kg^{-1}$)
FC (%)					
25	7.03a	7.98c	0.77c	55.03a	12.22a
50	7.04a	7.22d	0.78c	55.00a	12.34a
75	6.90b	11.72b	1.80b	50.15b	11.32b
100	6.75c	17.63a	2.22a	49.73b	10.68c
LSD	0.05	0.48	0.27	1.25	0.25
OF ($t\ ha^{-1}$)					
0	6.68b	10.41b	1.02c	24.67c	8.72c
5	7.08a	9.03c	1.78a	59.32b	12.77b
10	7.03a	13.98a	1.39b	73.43a	13.44a
LSD	0.04	0.42	1.08	1.08	0.22
AMF					
Zero	6.96a	10.90b	1.21b	47.46b	11.05c
GC	6.94ab	12.41a	1.72a	55.30a	11.52b
GD	6.90b	10.11c	1.26b	54.67a	12.35a
LSD	0.04	0.42	0.23	1.08	0.22

Mean(s) with the same letter in each column is/are not significantly different at $p < 0.05$.
Legend: GC = *Glomus clarum*, GD = *Glomus deserticola*, FC = Field capacity, OF = Organic fertilizer, AMF = Arbuscular mycorrhiza fungi.

These soil properties sustained the second *A. cruentus* cultivation without further soil amendment additions, but with a reduction in the yield of the test crop. Increased soil organic carbon and slightly acidic soil conditions were observed by Tits et al. (2014), Babajide and Olla (2014), and Okonji et al. (2018) in AMF treated soils.

The symbiotic association of AMF in plants that allows for more P as observed by Cundiff (2012) and Bhardwaj et al. (2014) was equally observed in this study (Table 2). Pots without AMF had significantly ($p < 0.05$) lower available

P of 47.46 mg kg^{-1} when compared with 54.67 and 55.30 mg kg^{-1} of available P for *G. deserticula* and *G. clarum* fungal additions, respectively.

Agronomic growth of *Amaranthus cruentus*

Growth parameters of *A. cruentus* improved with the use of organic fertilizer and the AM fungi. Moyin-Jesu (2015) earlier observed significant improvement in similar growth parameters with organic fertilizer treatments when compared to the control. However, there were reduced growth parameters during the second planting (Figures 1 to 4). Growth parameters increased with increasing rates of water addition, but varied slightly during the repeated experiment, where plants with 75% FC treatments had comparable growth with 100% FC treatment plants. This could be the reasonable soil moisture that allows for availability of nutrients to plants. This agreed with the findings of Khalil and Yousef (2014) where growth parameters of the test plant were significantly lowered with decreasing rates of water availability.

The highest mean plant height of 64.83 ± 6.72 cm obtained with the treatment containing 10 t ha^{-1} OF and *G. clarum* was not significantly different from 61.83 ± 4.91 cm obtained with the treatment containing 5 t ha^{-1} OF and *G. clarum* at 100% FC (Figure 1). Soil inoculation with *G. clarum* gave the best crop physiological growth parameters by Zuccarini and Savé (2016). At 75% FC, the highest mean plant height of 44.67 ± 5.36 cm was obtained with the treatment containing 10 t ha^{-1} OF and *G. deserticola*. The highest mean stem girth of 3.50 ± 0.00 cm was obtained with 10 t ha^{-1} OF and *G. deserticola* at 100% FC; while at 75% FC, the highest mean stem girth of 2.63 ± 0.07 cm was obtained with 10 t ha^{-1} OF (Figure 3). The highest mean leaf area of 98.51 ± 7.61 cm^2 was also obtained with the treatment containing 10 t ha^{-1} OF and *G. deserticola* (Figure 4). Comparable results were obtained during the second planting, though with reduced values. These results agreed with Minaxi et al. (2013) and Cyril et al. (2014) whose work showed the highest plant height of *A. cruentus* with the synergistic use of manure and AM fungi when combined, which was significantly higher than when each of the treatments was singly applied.

Yield of *Amaranthus cruentus*

The yield of *A. cruentus* plants as influenced by AM fungi and OF is shown in Tables 3 and 4. The highest vegetative yield of 73.23 g 3 kg^{-1} soil (48.82 t ha^{-1}) was obtained with the treatment containing 10 t ha^{-1} OF. This was significantly ($F_{72,107} = 67.43$; $p < 0.05$) different from 27.20 g 3 kg^{-1} soil (18.13 t ha^{-1}) at 100% FC in the control pots. The vegetative yield of *A. cruentus* with 10 t ha^{-1} OF, *G. deserticola* and 75% FC water regime was significantly ($p < 0.05$) higher than the control at 100% FC water regime. Other treatments at 75% FC water regime, apart from the control were not significantly different. This revealed that AM fungi and OF aided adaptation of *A. cruentus* plants from 75% FC water regime.

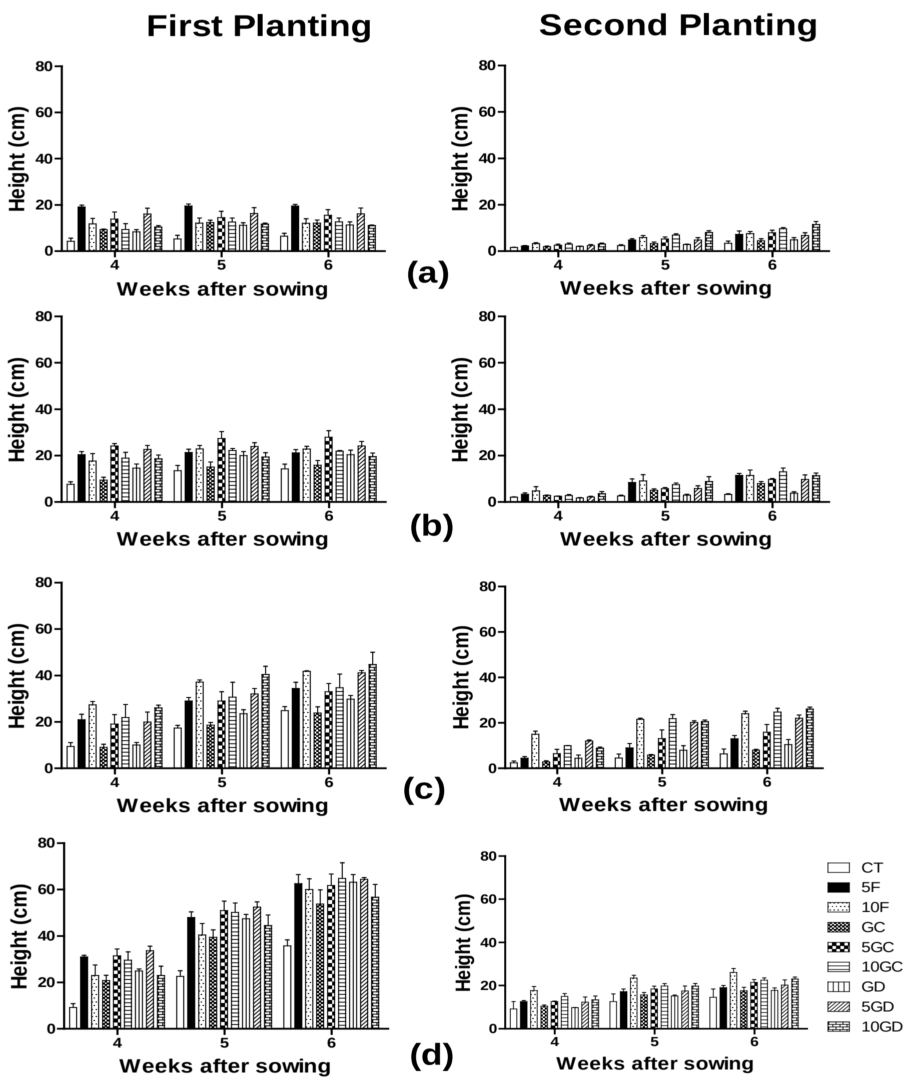


Figure 1. Mean plant height of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

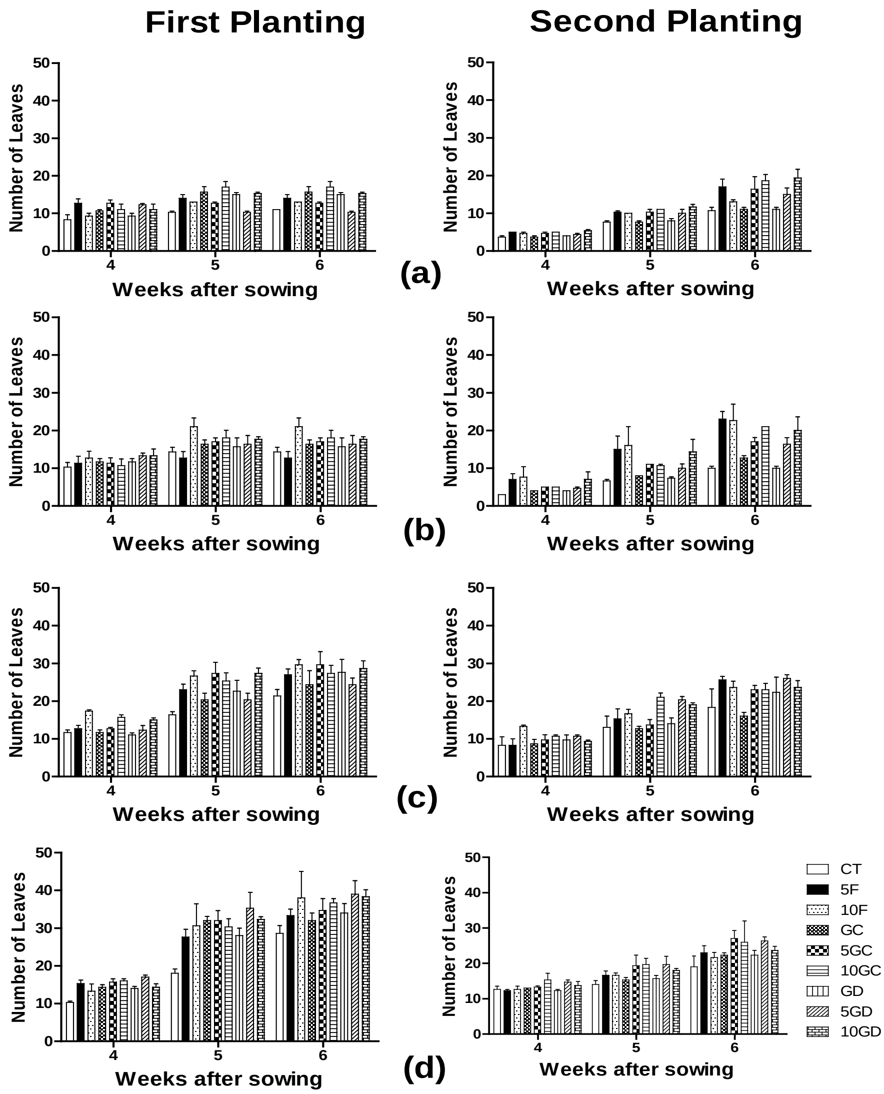


Figure 2. Mean number of leaves of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

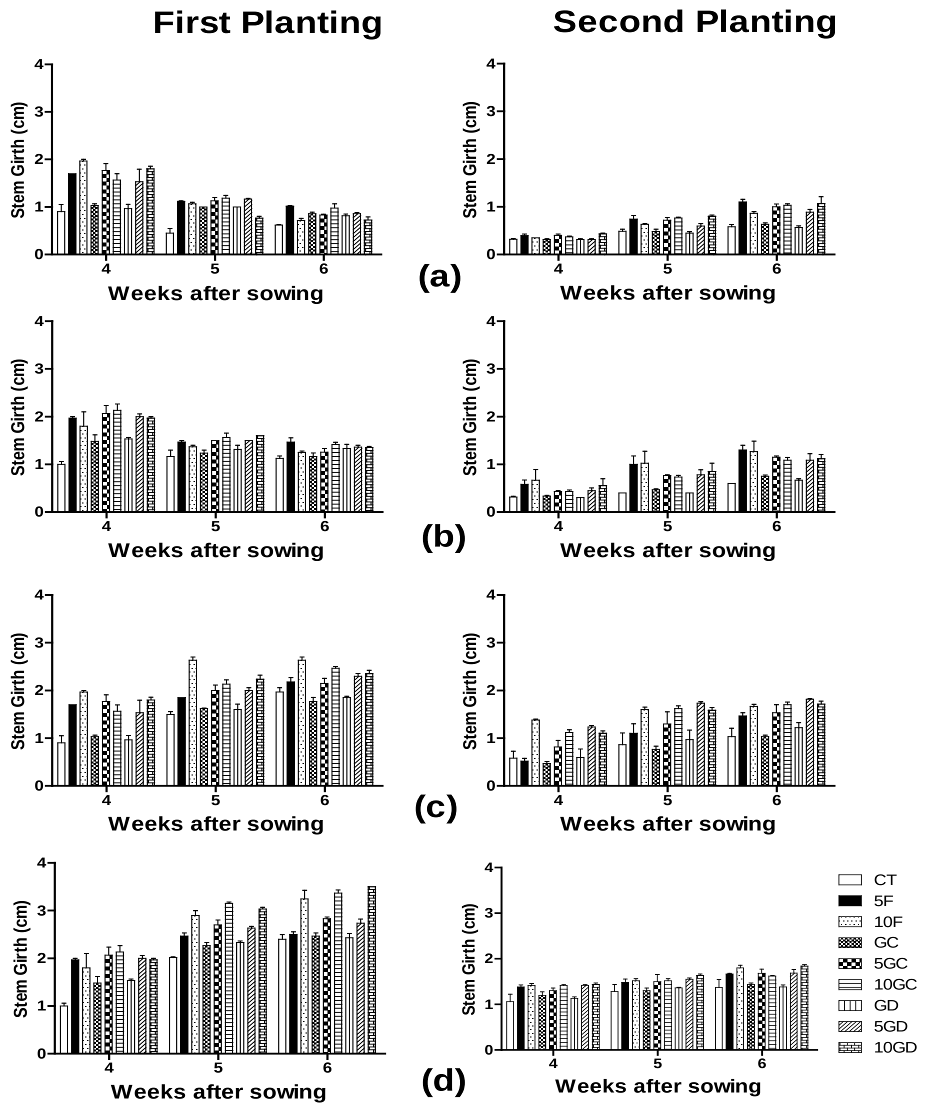


Figure 3. Mean stem girth of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

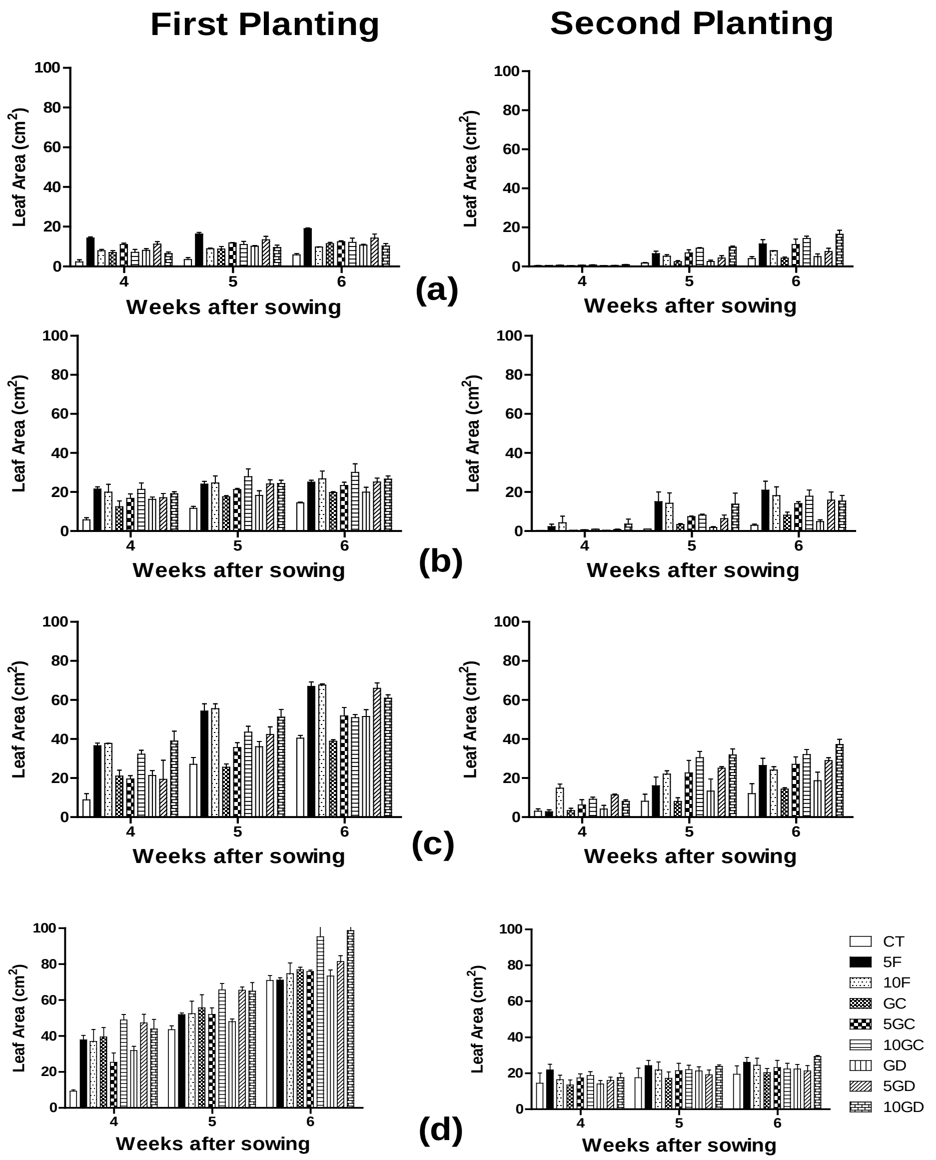


Figure 4. Mean leaf area of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

Table 3. Mean vegetative yield (g/3 kg soil) of *A. cruentus* at the first harvest.

Water regime	Treatment arbuscular mycorrhiza fungi	Organic fertilizer rate (t ha^{-1})	Fresh weight	Dry weight
A (25%)	Control	0	0.73j	0.28u
		5	2.37j	0.67stu
		10	1.50j	0.53tu
	Glomus clarum	0	1.87j	0.50tu
		5	1.80j	0.48tu
		10	2.17j	0.69stu
	Glomus deserticola	0	1.40j	0.41tu
		5	1.53j	0.40tu
		10	1.30j	0.43tu
B (50%)	Control	0	2.93j	0.85rstu
		5	5.10j	1.39opqr
		10	5.23j	1.40opqr
	Glomus clarum	0	3.23j	0.95qrst
		5	5.27j	1.51nopq
		10	4.97j	1.43opqr
	Glomus deserticola	0	5.80j	1.17qrs
		5	5.03j	1.42opqr
		10	4.37j	1.28pqr
C (75%)	Control	0	17.00i	2.05lmn
		5	27.47gh	2.80ijk
		10	26.37gh	2.47jkl
	Glomus clarum	0	16.23i	1.81mnop
		5	27.67gh	2.97ij
		10	31.43g	2.45jkl
	Glomus deserticola	0	18.93hi	1.94lmno
		5	29.57g	2.26klm
		10	39.80f	3.76h
D (100%)	Control	0	27.20gh	3.27hi
		5	68.67ab	8.47b
		10	57.60cd	4.86fg
	Glomus clarum	0	43.53ef	5.20ef
		5	58.67cd	7.21c
		10	73.23a	8.99a
	Glomus deserticola	0	50.43de	4.43g

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test.

Table 4. Mean vegetative yield (g/3 kg soil) of *A. cruentus* at the second harvest.

Water regime	Treatment arbuscular mycorrhiza fungi	Organic fertilizer rate (t ha^{-1})	Fresh weight	Dry weight
A (25%)	Control	0	0.85no	0.15mno
		5	2.54jklmno	0.59jklmno
		10	1.83klmno	0.44klmno
	Glomus clarum	0	0.78no	0.16mno
		5	2.97ijklmno	0.65jklmno
		10	3.60ijklmn	0.79jklmno
	Glomus deserticola	0	0.84no	0.16mno
		5	1.48mno	0.38lmno
		10	4.72hijkl	0.97ijklm
B (50%)	Control	0	0.35o	0.08o
		5	4.69hijkl	1.01ijkl
		10	5.83fghi	1.25ghijk
	Glomus clarum	0	1.76lmno	0.39lmno
		5	4.27ijklm	0.79jklmno
		10	5.52hij	0.94jklmn
	Glomus deserticola	0	0.70no	0.13no
		5	5.24hij	0.75jklmno
		10	3.52ijklmn	0.88jklmno
C (75%)	Control	0	3.13ijklmno	0.77jklmno
		5	6.04fghi	1.37fghij
		10	11.07bc	2.68abc
	Glomus clarum	0	4.29ijklm	0.74jklmno
		5	7.59efgh	1.94cdefgh
		10	11.24abcd	2.65abc
	Glomus deserticola	0	5.69ghi	1.18hijkl
		5	8.58defg	2.59abcd
		10	13.96a	2.38bcde
D (100%)	Control	0	4.88hijk	1.73efghi
		5	11.44abcd	3.18a
		10	12.53abc	2.69abc
	Glomus clarum	0	7.49efgh	1.83defgh
		5	9.71cde	2.00bcdefg
		10	12.78ab	2.78ab
	Glomus deserticola	0	8.70def	2.10bcdef
		5	10.09bcde	2.13bcdef
		10	12.90ab	2.79ab

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test.

The findings of Khalil and Yousef (2014) supported the findings that higher soil moisture could lead to higher yield of crops, and also Okonji et al. (2018) observed the enhanced yield of rice when soil was inoculated with AMF.

The repeated experiment without further application of AM fungi and OF treatments gave lower and comparable values. These results agreed with the findings of Cyril et al. (2014) where the application of manure in combination with AM fungi showed a significantly higher vegetative yield of *A. cruentus* than the control or the use of inorganic fertilizer. Salami and Osonubi (2003) similarly recorded the improved cassava yield with AM fungi inoculation, and Bona et al. (2016) equally showed that AM fungi were useful for sustainable agriculture.

Conclusion

The synergistic use of AM fungi and organic fertilizer improved the availability of total N, organic C and CEC of the soil. The growth and yield of *A. cruentus* cultivated under different soil moisture regimes when AM fungi and organic fertilizer were applied also varied. The addition of *G. clarum* fungi with 5 t ha^{-1} of organic fertilizer to soil optimally improved the growth and yield of *A. cruentus* in water stress conditions.

References

Afshar, R.K., Chaichi, M.R., Rezaei, K., Asareh, M.H., Karimi, M., & Hashemi, M. (2014). Irrigation regime and organic fertilizers influence on oil content and fatty acid composition of milk thistle seeds. *Agronomy, Soils and Environmental Quality*, *107* (1), 187-194.

Agneessens, L., De Waele, J., & De Neve, S. (2014). Review of alternative management options of vegetable crop residues to reduce nitrate leaching in intensive vegetable rotations. *Agronomy*, *4* (4), 529-555.

Aguilera, E., Lassaletta, L., Sanz-Cobena, A., Garnier, J., & Vallejo, A. (2013). The potential of organic fertilizers and water management to reduce N_2O emissions in mediterranean climate cropping systems - A review. *Agriculture, Ecosystems and Environment*, *164*, 32-52.

Ajiboye, A.A., Fadimu, O.Y., Ajiboye, M.D., Agboola, D.A., Adelaja, A.B., & Bem, A.A. (2014). Phytochemical and nutritional constituents of some common vegetables in Southwest, Nigeria. *Global Journal of Science Frontier Research*, *14* (3), 49-53.

Armada, E., López-Castillo, O., Roldán, A., & Azcón, R. (2016). Potential of mycorrhizal inocula to improve growth, nutrition and enzymatic activities in *Retama sphaerocarpa* compared with chemical fertilization under drought conditions. *Journal of Soil Science and Plant Nutrition*, *16* (2), 380-399.

Babajide, P.A., & Olla, N.O. (2014). Performance of indigenous *Celosia argentea* variety and soil physico-chemical properties as affected by dual application of compost and single N-mineral fertilizer in southern guinea savanna vegetation zone of Nigeria. *Journal of Biology, Agriculture and Healthcare*, *4* (19), 69-75.

Bhardwaj, D., Ansari, M.W., Sahoo, R.K., & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, *13* (66), 1-10.

Bona, E., Cantamessa, S., Massa, N., Manassero, P., Marsano, F., Copetta, A., Lingua, G., D'Agostino, G. Gamalero, E., & Berta, G. (2016). Arbuscular mycorrhizal fungi and plant growth-promoting Pseudomonads improve yield, quality and nutritional value of tomato: A field study. *Mycorrhiza*, *27*, 1-11.

Borie, F., Rubio, R., Morales, A., Curaqueo, G., & Cornejo, P. (2010). Arbuscular mycorrhizae in agricultural and forest ecosystems in Chile. *Journal of Soil Science and Plant Nutrition*, *10* (3), 185-206.

Chemura, A. (2014). The growth response of coffee (*Coffea arabica* L.) plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation water supply levels. *International Journal of Recycling of Organic Waste in Agriculture*, *3*, 1-59.

Cundiff, G.T. (2012). *Using arbuscular mycorrhizae to influence yield, available soil nutrients and soil quality in conventional vs. organic vegetable production.* Western Kentucky University, Bowling Green, Kentucky, USA.

Cyril, C.N., Kehinde, O.O., Olanrewaju, A.D., David, S.D., & Aderemi-Williams, O. (2014). Vegetative growth and yield response of *Amaranthus cruenthus* to arbuscular mycorrhizal fungi (AMF), poultry manure (PM), combination of AMF-PM and inorganic fertilizer. *American Journal of Experimental Agriculture*, *4* (6), 665-673.

Eulenstein, F., Tauschke, M., Behrendt, A., Monk, J., Schindler, U., Lana, M.A., & Monk, S. (2017). The application of mycorrhizal fungi and organic fertilisers in horticultural potting soils to improve water use efficiency of crops. *Horticulturae*, *3* (1), 1-8.

Ge, S., Xu, H., Ji, M., & Jiang, Y. (2013). Characteristics of soil organic carbon, total nitrogen, and C/N ratio in Chinese apple orchards. *Open Journal of Soil Science*, *3*, 213-217.

Habte, H., & Osorio, N.W. (2001). Arbuscular mycorrhizas: Producing and applying arbuscular mycorrhizal inoculums. College of Tropical Agriculture and Human Resources, University of Hawaii, Hawaii, USA.

Joshi, R., Singh, J., & Vig, A.P. (2014). Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Reviews in Environmental Science and BioTechnology*, *13* (3), 1-23.

Khalil, S.E., & Yousef, R.M. (2014). Interaction effects of different soil moisture levels, arbuscular mycorrhizal fungi and three phosphate levels on: growth, yield and photosynthetic activity of garden cress (*Lepidium sativum* L.) plant. *International Journal of Advanced Research*, *2* (6), 723-737.

Lehtinen, T., Schlatter, N., Baumgarten, A., Bechini, L., Krüger, J., Grignani, C., Zavattaro, L., Costamagna, C., & Spiegel, H. (2014). Effect of crop residue incorporation on soil organic carbon and greenhouse gas emissions in European agricultural soils. *Soil Use and Management*, *30* (4), 524-538.

Medina, A., & Azcon, R. (2010). Effectiveness of the application of arbuscular mycorrhiza fungi and organic amendments to improve soil quality and plant performance under stress conditions. *Journal of Soil Science and Plant Nutrition*, *10* (3), 354-372.

Minaxi, S.J., Chandra, S., & Nain, L. (2013). Synergistic effect of phosphate solubilizing rhizobacteria and arbuscular mycorrhiza on growth and yield of wheat plants. *Journal of Soil Science and Plant Nutrition*, *13* (2), 511-525.

Moyin-Jesu, E.I. (2015). Use of different organic fertilizers on soil fertility improvement, growth and head yield parameters of cabbage (*Brassica oleraceae* L). *International Journal of Recycling of Organic Waste in Agriculture*, *4* (4), 291-298.

Mshelmbula, B.P., Florence, L., Midawa, S.M., & Yusuf, C.S. (2017). Genetic responds of two varieties of *Amaranthus* on diffrerent salinity concentrations grown in Mubi, Nigeria. *Applied Science Reports*, *17* (3), 63-71.

Murrell, E.G., Hanson, C.R., & Cullen, E.M. (2015). European corn borer oviposition response to soil fertilization practices and arbuscular mycorrhizal colonization of corn. *Ecosphere*, *6* (6), 1-12.

Okon, I.E., & Solomon, M.G. (2014). Arbuscular mycorrhiza fungi status of some crops in the Cross River Basin of Nigeria. *Global Journal of Pure and Applied Sciences*, *20*, 5-9.

Okonji, C.J., Sakariyawo, O.S., Okeleye, K.A., Osunbiyi, A.G., & Ajayi, E.O. (2018). Effects of arbuscular mycorrhizal fungi inoculation on soil properties and yield of elected rice varieties. *Journal of Agricultural Sciences*, *63* (2), 153-170.

Page, A.L., Miller, R.H., & Keeney, D.R. (1982). *Methods of soil analysis, part 2, chemical and microbiological properties.* American Society of Agronomy, Inc., Madison, WI, USA.

Rana, K.N., Patel, G.J., Desai, C.K., & Akbari, M.P. (2017). Quality of Amaranthus (*Amaranthus hypochondriacus* L.) and soil properties influenced by irrigation scheduling based on critical growth stages and levels of iron. *Journal of Pharmacognosy and Phytochemistry, 6* (5), 101-103.

Salami, A.O., & Osonubi, O. (2003). Influence of mycorrhizal inoculation and different pruning regimes on fresh root yield of alley and sole cropped cassava (*Manihot esculenta Crantz*) in Nigeria. *Archives of Agronomy and Soil Science, 49* (3), 317-323.

Salehi, A., Tasdighi, H., & Gholamhoseini, M. (2016). Evaluation of proline, chlorophyll, soluble sugar content and uptake of nutrients in the German chamomile (*Matricaria chamomilla* L.) under drought stress and organic fertilizer treatments. *Asian Pacific Journal of Tropical Biomedicine, 6* (10), 886-891.

Tits, A.M., Elsen, A., Bries, J., & Vandendriessche, H. (2014). Short-term and long-trem effects of vegetable, fruit and garden waste compost applications in an arable crop rotation in Flanders. *Plant and Soil*, *376* (1/2), 43-59.

Towolawi, A.T., Arowolo, T.A., Bada, B.S.,Badejo, A.A., & Taiwo, A.M. (2017). Phytoextraction assessment of green Amaranth (*Amaranthus viridis* Linn.) grown on soil amended with sewage sludge. *Ife Journal of Science, 19* (1), 133-140.

Vandenberghe, L.P., Garcia, L.M., Rodrigues, C., Camara, M.C., Pereira, G.V., de Oliveira, J., & Soccol, C.R. (2017). Potential applications of plant probiotic microorganisms in agriculture and forestry. *AIMS Microbiology, 3* (3), 629-648.

Widowati, L.R., & De Neve, S. (2016). Nitrogen dynamics and nitrate leaching in intensive vegetable rotations in highlands of central Java, Indonesia. *Journal of Tropical Soils, 21* (2), 67-78.

Zhigila, D.A., Yuguda, U.A., Akawu, J.J., & Oladele, F.A. (2014). Palynomorphs and floral bloom as taxonomic characters in some species of the genus *Amaranthus* L. (*Amaranthaceae*). *Bayero Journal of Pure and Applied Sciences, 7* (2), 164-168.

Zuccarini, P., & Savé, R. (2016). Three species of arbuscular mycorrhizal fungi confer different levels of resistance to water stress in *Spinacia oleracea* L. *Plant Biosystems, 150* (5), 851-854.

Received: October 22, 2018
Accepted: May 9, 2019

UTICAJI ARBUSKULARNIH MIKORIZNIH GLJIVA, ORGANSKOG ĐUBRIVA I RAZLIČITIH REŽIMA VLAGE NA OSOBINE ZEMLJIŠTA I PRINOS BILJKE *AMARANTHUS CRUENTUS*

Adebisi E. Adekanmbi i Moses B. Adewole*

Institut za studije ekologije i zaštite životne sredine,
Univerzitet Obafemi Awolowo, Ile-Ife, Nigerija

R e z i m e

Ogled je sproveden u sudovima kako bi se procenio uticaj dve arbuskularne mikorizne (AM) gljive i organskog đubriva (engl. *organic fertilizer* – OF) na rast i prinos biljke *Amaranthus cruentus* pri različitim režimima vlage zemljišta. Ovo je urađeno u cilju pružanja informacija o adaptaciji useva na uslove suše i kako bi se održala ravnoteža hranljivih materija u zemljištu u cilju povećanja prinosa useva. Ogled se sastojao od 36 tretmana (*Glomus clarum, Glomus deserticola* i bez AM), organskog đubriva proizvedenog od pijačnog otpada u različitim količinama (0, 5 i 10 t ha^{-1}) i različitih vodnih režima (25, 50, 75 i 100% poljskog kapaciteta [engl. *field capacity* – FC]). Svaki tretman ogleda je postavljen u tri ponavljanja. Kombinacijom tretmana, 10 t ha^{-1} OF i *G. clarum* dobijen je najveći sveži vegetativni prinos – 48,82 t ha^{-1}, koji nije statistički značajno ($p>0,05$) odstupao samo od tretmana sa 5 t ha^{-1} OF i *G. clarum* (45,78 t ha^{-1}) pri poređenju vodnih režima. Ponovljenim ogledom samo sa dodavanjem vode, dobijeni su niži i uporedivi prinosi biljke *A. cruentus*. Može se zaključiti da je dodavanje *G. clarum* zemljištu u kombinaciji sa 5 t ha^{-1} organskog đubriva optimalno poboljšalo rast i prinos biljke *A. cruentus* u uslovima vodnog stresa.

Ključne reči: arbuskularne mikorizne gljive, organsko đubrivo, vodni stres, *Amaranthus cruentus*, pijačni otpad.

Primljeno: 22. oktobra 2018.
Odobreno: 9. maja 2019.

*Autor za kontakt: e-mail: mbadewole@gmail.com

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 165-174

https://doi.org/10.2298/JAS1902165M
UDC: 634.22-154.1(497.11)"2013/2018"
Original scientific paper

UTICAJ PODLOGA NA RAST, RODNOST I KVALITET PLODA SORTE ŠLJIVE ČAČANSKA RANA

Dragan P. Milatović[1*], Mirjana M. Radović[2], Gordan N. Zec[1] i Đorđe D. Boškov[1]

[1]Univerzitet u Beogradu, Poljoprivredni fakultet,
Nemanjina 6, 11080 Beograd-Zemun, Srbija
[2]Univerzitet u Istočnom Sarajevu, Poljoprivredni fakultet,
Vuka Karadžića 30, 71123 Istočno Sarajevo, Bosna i Hercegovina

Sažetak: U radu je ispitivan uticaj tri vegetativne podloge (Pixy, Fereley i St. Julien A) i sejanaca džanarike (kontrola) na rast, rodnost i kvalitet ploda sorte šljive Čačanska rana. Istraživanje je obavljeno na području beogradskog Podunavlja u periodu od šest godina (2013–2018). U odnosu na kontrolu, sve tri vegetativne podloge su ispoljile značajan uticaj na smanjenje bujnosti izražene preko površine poprečnog preseka debla. Najmanja bujnost je bila kod stabala na podlozi Pixy, zatim Fereley i St. Julien A. Na podlogama Fereley i St. Julien A dobijeno je značajno veće zametanje plodova, kao i prinos po stablu u odnosu na kontrolu. Na vegetativnim podlogama prinos po hektaru bio je veći za 72% do 93% u odnosu na džanariku. Najveći koeficijent rodnosti imala su stabla na podlozi Fereley, a za njom slede Pixy i St. Julien A. Značajno veća masa ploda u odnosu na kontrolu dobijena je kod stabala na podlozi Fereley. Podloge nisu ispoljile značajan uticaj na sadržaj rastvorljive suve materije i ukupnih kiselina u plodu. Na osnovu dobijenih rezultata, može se zaključiti da su sve tri vegetativne podloge dale bolje rezultate u odnosu na džanariku i mogu se preporučiti za podizanje intenzivnih zasada šljive sa većom gustinom sadnje. Najbolji rezultati u pogledu rodnosti i kvaliteta ploda dobijeni su kod podloge Fereley.

Ključne reči: *Prunus domestica*, vegetativne podloge, bujnost, prinos, kvalitet ploda.

Uvod

Evropska šljiva (*Prunus domestica* L.) je po proizvodnji na prvom mestu među voćkama u Srbiji. Iako je ukupna godišnja proizvodnja velika (prosečno 437.008 t za period 2013–2017. godine), prosečan prinos po jedinici površine je relativno mali – 5,86 t/ha (Republički zavod za statistiku Srbije, 2018). Osnovni

[*]Autor za kontakt: e-mail: mdragan@agrif.bg.ac.rs

razlog za to je u velikoj meri ekstenzivna proizvodnja, sa velikim razmacima sadnje i nedovoljnom primenom agrotehničkih i pomotehničkih mera.

Najveći deo proizvedenih plodova šljive u Srbiji se preradi u rakiju (više od 70%). Znatno manje količine se koriste za sušenje i druge vidove prerade. Potrošnja plodova u svežem stanju je vrlo mala. Jedna od najviše gajenih stonih sorti šljive je Čačanska rana. Ova sorta ima vrlo krupne plodove, sazreva rano, početkom jula, a plodovi postižu visoku cenu na tržištu. Međutim, problemi kod ove sorte su velika bujnost i slabija rodnost (Sosna, 2002; Milatović et al., 2018).

Glavna podloga za šljivu u Srbiji su sejanci džanarike (*Prunus cerasifera* Ehrh). Oni su zastupljeni sa više od 95% u proizvodnji sadnica šljive. Sejanci džanarike se odlikuju velikom bujnošću i dosta su neujednačeni (heterogeni). Sorte šljive kalemljene na džanarici su bujne i kasno stupaju u period rodnosti.

Korišćenjem vegetativnih podloga slabije bujnosti može se povećati gustina sadnje, kao i prinos po jedinici površine, te omogućiti lakša primena pomotehničkih mera kao što su rezidba i berba. U poslednjih dvadeset godina objavljeni su brojni rezultati istraživanja uticaja vegetativnih podloga na smanjenje bujnosti i povećanje prinosa sorti šljive po jedinici površine (Botu et al., 2002; Kosina, 2004; Sitarek et al., 2004; Meland, 2010; Blažek i Pištěková, 2012; Mészáros et al., 2015). Nove vegetativne podloge u kombinaciji sa uzgojnim oblikom mogu poslužiti kao osnova za podizanje savremenih zasada šljive sa većom gustinom sklopa (Magyar i Hrotkó, 2006).

Cilj ovog rada je ispitivanje bujnosti, rodnosti i kvaliteta ploda sorte šljive Čačanska rana okalemljene na tri vegetativne podloge u poređenju sa sejancima džanarike. Takođe, ovaj ogled treba da oceni pogodnost različitih podloga za gajenje šljive u sistemu guste sadnje.

Materijal i metode

Istraživanja su obavljena na Oglednom dobru „Radmilovac" Poljoprivrednog fakulteta Univerziteta u Beogradu. Predmet istraživanja je bila sorta šljive Čačanska rana, koja je okalemljena na četiri različite podloge. Od toga, tri su vegetativne podloge: Fereley (Jaspi), Pixy i St. Julien A (Saint Julien A), dok je četvrta podloga bila generativna – sejanci džanarike (*Prunus cerasifera* Ehrh), koji su korišćeni kao kontrola.

Ogledni zasad je posađen u proleće 2010. godine. Razmak sadnje je bio 4 m između redova, dok su u redu primenjena različita rastojanja u zavisnosti od bujnosti podloge: 2,3 m za sejance džanarike, 2 m za podloge Fereley i St. Julien A i 1,7 m za podlogu Pixy. Svaka varijanta ogleda (podloga) bila je zastupljena sa po šest stabala (dva ponavljanja sa po tri stabla). Uzgojni oblik je vitko vreteno. U zasadu su primenjivane standardne agrotehničke i pomotehničke mere, uključujući navodnjavanje kapanjem i letnju rezidbu. Istraživanja su obavljena u periodu od šest godina (2013–2018). Starost stabala u periodu ispitivanja je bila od četiri do devet godina. Pored sorte Čačanska rana, u eksperimentalnom zasadu su posađene i sorte Čačanska lepotica i Čačanska najbolja.

Bujnost je određivana na osnovu površine poprečnog preseka debla. Ona je izračunata na osnovu merenja obima debla koje je izvedeno na visini od 20 cm iznad spojnog mesta podloge i plemke. Zametanje plodova je određivano na osnovu slobodnog oprašivanja na šest odabranih grana (dva ponavljanja sa po tri grane) na svakoj od podloga. Svaka odabrana grana je imala najmanje 100 cvetova. Zametnuti plodovi su prebrojavani oko 10 dana pre berbe. Zametanje je izračunato kao odnos broja zametnutih plodova i broja cvetova i izraženo je u %. Koeficijent rodnosti je izračunat kao odnos kumulativnog prinosa po stablu za šest godina (2013–2018) i površine poprečnog preseka debla u poslednjoj, šestoj godini istraživanja (2018) i izražen je u kg/cm^2. Osobine ploda (masa ploda i koštice, dimenzije ploda i dužina peteljke) određivane su merenjem pojedinačnih plodova na uzorku od 60 plodova od svake varijante (10 plodova po stablu). Indeks oblika ploda je izračunat korišćenjem formule: $IO = D^2/(Š \times Db)$, gde su: D – dužina, Š – širina i Db – debljina ploda. Rastvorljive suve materije su određivane pomoću refraktometra (Pocket PAL-1, Atago, Japan). Ukupne kiseline su određene titracijom sa NaOH i izražene su kao jabučna kiselina.

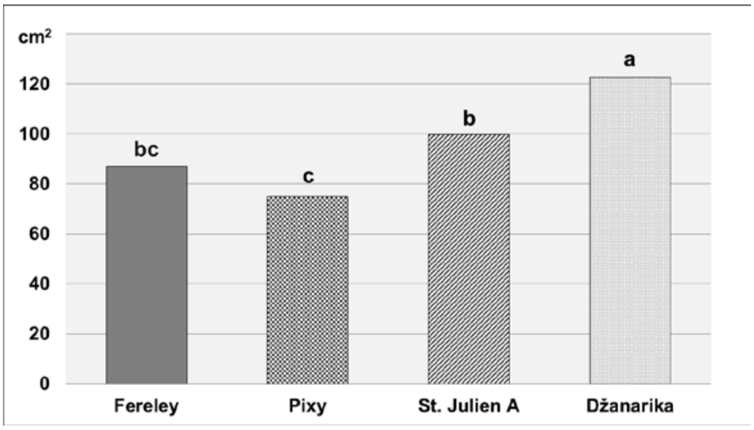
Statistička obrada podataka obavljena je metodom analize varijanse. Značajnost razlika između srednjih vrednosti određena je uz pomoć Dankanovog testa višestrukih intervala za nivo značajnosti $P \leq 0,05$. Statistička analiza je obavljena korišćenjem programa IBM SPSS Statistics 20 (SPSS Inc, Chicago, IL, USA).

Rezultati i diskusija

Kao pokazatelj bujnosti voćaka najčešće se koristi površina poprečnog preseka debla (PPPD). Među ispitivanim podlogama utvrđene su statistički značajne razlike u pogledu PPPD (slika 1).

U devetoj godini nakon sadnje, najveća PPPD (122,7 cm^2) je ustanovljena kod stabala na podlozi džanarika, dok je najmanja vrednost (74,9 cm^2) utvrđena kod stabala na podlozi Pixy. Sve tri vegetativne podloge su imale statistički značajno manje vrednosti PPPD u odnosu na kontrolu (džanarika). Smanjenje PPPD u odnosu na kontrolnu varijantu (džanarika) je iznosilo 39% kod podloge Pixy, 29% kod podloge Fereley i 19% kod podloge St. Julien A.

Dobijeni rezultati slabe bujnosti stabala šljive na podlozi Pixy u skladu su sa prethodno objavljenim rezultatima (Sosna, 2002; Kosina, 2004; Sitarek et al., 2004). Prema ispitivanjima u Rumuniji, Pixy spada u polupatuljaste podloge, a prosečna PPPD za devet okalemljenih sorti bila je 35% manja u odnosu na sejanac džanarike (Botu et al., 2002). U istom istraživanju, podloga St. Julien A je uticala na smanjenje PPPD sorti za prosečno 29%.



Slika 1. Površina poprečnog preseka debla sorte šljive Čačanska rana na različitim podlogama u 2018. godini.
Figure 1. The trunk cross-sectional area of the plum cultivar Čačanska rana on different rootstocks in 2018.
Različita slova iznad stubića označavaju statistički značajne razlike na osnovu Dankanovog testa (P≤0,05).
Different letters above the bars indicate statistically significant differences according to Duncan's test (P≤0.05).

Zametanje plodova je jedan od najznačajnijih pokazatelja rodnosti voćaka (Glišić et al., 2012; Nikolić et al., 2012). Rezultati zametanja plodova pri slobodnom oprašivanju kod sorte šljive Čačanska rana kalemljene na različitim podlogama prikazani su u tabeli 1.

Tabela 1. Zametanje plodova sorte šljive Čačanska rana na različitim podlogama (%).
Table 1. The fruit set of the plum cultivar Čačanska rana on different rootstocks (%).

Podloge *Rootstocks*	Godine/*Years*						Prosek *Average*
	2013.	2014.	2015.	2016.	2017.	2018.	
Fereley	12,3	11,8	10,5	11,6	10,1	10,7	11,2 a
Pixy	6,1	8,9	13,1	9,5	6,1	12,2	9,3 ab
St. Julien A	5,9	11,1	14,1	10,8	8,4	15,2	10,9 a
Džanarika (kontrola)	7,0	6,7	13,5	3,7	3,4	6,5	6,8 b

Srednje vrednosti označene istim slovom ne razlikuju se značajno prema Dankanovom testu (P≤0,05).
Mean values followed by the same letter are not significantly different according to Duncan's test (P≤0.05).

Zametanje plodova kod sorte Čačanska rana variralo je u rasponu od 3,4% na podlozi džanarika u 2017. godini do 15,2% na podlozi St. Julien A u 2018. godini.

Između podloga su utvrđene statistički značajne razlike kada je u pitanju zametanje plodova. U odnosu na kontrolu (sejanci džanarike) statistički značajno veće prosečno zametanje plodova utvrđeno je kod stabala na podlogama Fereley i St. Julien A.

Dobijeni rezultati o zametanju plodova šljive pri slobodnom oprašivanju su u granicama koje navode drugi autori. Kod 21 sorte šljive Surányi (2006) je dobio prosečno zametanje plodova u rasponu od 10,9% do 44,4%. Ispitivanjem šest hibrida šljive Glišić et al. (2012) su utvrdili zametanje plodova u granicama 7,6–30,6%. Kod 10 sorti šljive Jaćimović et al. (2012) su ustanovili zametanje plodova od 10,5% do 20,3%, a među ispitivanim sortama bila je i Čačanska rana kod koje je ono iznosilo 15,5%.

Za sorte evropske šljive Neumüller (2011) daje sledeću klasifikaciju na osnovu stepena zametanja plodova: nisko (ispod 10%), srednje (10–20%), visoko (20–40%) i vrlo visoko (iznad 40%). Na osnovu ove podele, prema dobijenim rezultatima u ovom radu, Čačanska rana bi bila u grupi sorti sa niskim do srednjim zametanjem plodova. Jedan od najznačajnijih faktora koji utiče na zametanje plodova šljive je samooplodnost sorti. Niži stepen zametanja plodova sorte Čačanska rana može se objasniti time da je ona samobesplodna (autoinkompatibilna) sorta (Nikolić i Milatović, 2010).

Ispitivane podloge ispoljile su značajne razlike u pogledu uticaja na prinos po stablu (tabela 2). Najviši prosečan prinos po stablu dobijen je na podlozi Fereley (14,5 kg), dok je najniži prinos bio na džanarici (8,7 kg). U odnosu na kontrolu (sejance džanarike), statistički značajno viši prinos dobijen je kod stabala na podlogama Fereley i St. Julien A. Prinos na ove dve podloge je bio viši za 67%, odnosno 49%.

Tabela 2. Prinos sorte šljive Čačanska rana na različitim podlogama.
Table 2. The yield of the plum cultivar Čačanska rana on different rootstocks.

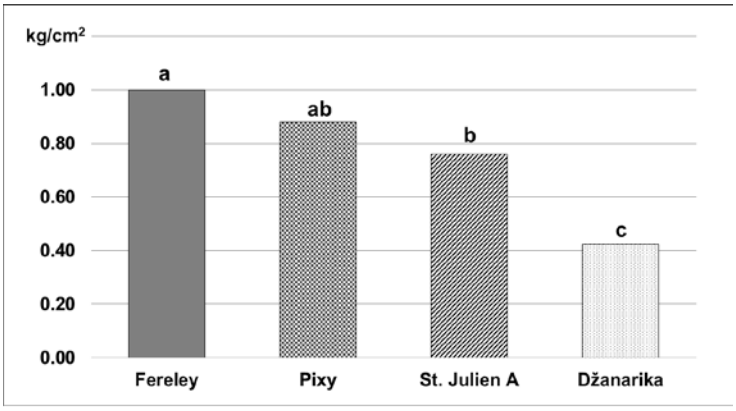
Podloge *Rootstocks*	Prinos (kg po stablu) *Yield (kg per tree)*							Prosečan prinos *Average yield* (t/ha)
	2013.	2014.	2015.	2016.	2017.	2018.	Prosek *Average*	
Fereley	18,1	23,9	14,1	8,4	9,7	12,8	14,5 a	18,1
Pixy	11,7	18,9	4,5	8,7	8,0	14,4	11,0 ab	16,2
St. Julien A	11,8	18,8	8,8	13,6	6,4	18,7	13,0 a	16,3
Džanarika (kontrola)	6,5	13,6	9,6	8,0	4,6	9,7	8,7 b	9,4

Srednje vrednosti označene istim slovom ne razlikuju se značajno prema Dankanovom testu (P≤0,05).
Mean values followed by the same letter are not significantly different according to Duncan's test (P≤0.05).

Ukoliko se prinos izrazi po jedinici površine (t/ha), razlike između podloga još više dolaze do izražaja. Kod stabala na vegetativnim podlogama dobijen je prinos od 16,2 do 18,1 t/ha. U odnosu na džanariku, prinos po hektaru je bio veći za 72% do 93%.

Viši prinos na vegetativnim podlogama može se delimično objasniti uticajem podloga na veće zametanje plodova. S druge strane, utvrđeno je da su ispitivane vegetativne podloge uticale i na povećanje broja cvetnih pupoljaka na rodnim grančicama, što je naročito bilo izraženo kod podloge Fereley (Radović et al., 2016). Naši rezultati potvrđuju prethodne navode o pozitivnom uticaju podloge Fereley na povećanje prinosa okalemljenih sorti šljive (Grzyb i Sitarek, 2006; Ogašanović et al., 2011).

Među ispitivanim podlogama utvrđene su i značajne razlike u pogledu uticaja na kumulativni koeficijent rodnosti (KKR) za period od šest godina (slika 2). Kod sve tri vegetativne podloge KKR je bio statistički značajno viši u odnosu na sejance džanarike.



Slika 2. Kumulativni koeficijent rodnosti sorte šljive Čačanska rana na različitim podlogama.
Figure 2. The cumulative yield efficiency of the plum cultivar Čačanska rana on different rootstocks.
Različita slova iznad stubića označavaju statistički značajne razlike na osnovu Dankanovog testa (P≤0,05).
Different letters above the bars indicate statistically significant differences according to Duncan's test (P≤0.05).

Dobijeni rezultati za koeficijent rodnosti kod sorte Čačanska rana su u skladu sa prethodnim istraživanjima kod ove sorte (Sosna, 2002; Glišić et al., 2016).

Masa ploda sorte Čačanska rana imala je prosečne vrednosti u rasponu od 57,3 g na džanarici do 61,3 g na podlozi Fereley (tabela 3). U odnosu na kontrolu, statistički značajno veću masu ploda imali su plodovi sa stabala na podlozi Fereley. Masa koštice je bila značajno veća kod plodova sa stabala na podlozi St. Julien A. Od ostalih osobina ploda, uočen je statistički značajan uticaj podloge Fereley na povećanje indeksa oblika ploda, tj. na izduženiji oblik ploda u odnosu na kontrolu.

Tabela 3. Osobine ploda sorte šljive Čačanska rana na različitim podlogama (prosečne vrednosti za period 2013–2018. godine).
Table 3. Fruit characteristics of the plum cultivar Čačanska rana on different rootstocks (average values for the 2013–2018 period).

Podloge *Rootstocks*	Masa ploda *Fruit weight* (g)	Masa koštice *Stone weight* (g)	Randman mesa *Flesh ratio* (%)	Indeks oblika *Fruit shape index*	Dužina peteljke *Pedicel length* (cm)	R. suva materija *Soluble solids* (%)	Ukupne kiseline *Total acids* (%)
Fereley	61,3 a	2,93 b	95,2	1,73 a	1,92	13,1	1,11
Pixy	57,9 ab	3,05 ab	94,7	1,64 ab	2,00	12,8	1,11
St. Julien A	61,0 ab	3,16 a	94,8	1,64 ab	1,96	11,9	1,06
Džanarika	57,3 b	2,91 b	94,9	1,61 b	1,93	13,0	1,06

Srednje vrednosti označene istim slovom u okviru jedne kolone ne razlikuju se značajno prema Dankanovom testu višestrukih intervala ($P \leq 0,05$).
Mean values followed by the same letter within a column are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

U literaturi se sreću različiti podaci o uticaju podloge na krupnoću ploda sorti šljive. U nekim istraživanjima dobijene su značajne razlike između podloga (Grzyb i Sitarek, 2006; Rato et al., 2008), dok u drugim te razlike nisu bile značajne (Hrotkó et al., 2002; Sosna, 2002; Kosina, 2004; Meland, 2010; Reig et al., 2018). Naša proučavanja su pokazala da je samo podloga Fereley ispoljila statistički značajan uticaj na povećanje krupnoće ploda u odnosu na džanariku, što potvrđuje rezultate koje su dobili Grzyb i Sitarek (2006).

U našem istraživanju nisu utvrđene značajne razlike u pogledu uticaja podloga na sadržaj rastvorljive suve materije i ukupnih kiselina. To je u saglasnosti sa prethodnim istraživanjima kod šljive (Meland, 2010; Milošević i Milošević, 2012; Reig et al., 2018).

Zaključak

Sve tri ispitivane vegetativne podloge (Fereley, Pixy i St. Julien A) ispoljile su pozitivan uticaj na smanjenje bujnosti i povećanje prinosa sorte šljive Čačanska rana. Najmanja bujnost ustanovljena je kod stabala na podlozi Pixy, a za njom slede podloge Fereley i St. Julien A. S druge strane, najveći prinos je dobijen kod podloge Fereley, a za njom slede St. Julien A i Pixy. Među ispitivanim podlogama, najbolje rezultate u pogledu rodnosti i kvaliteta ploda dala je podloga Fereley, tako da se ona može preporučiti za podizanje intenzivnih zasada šljive sa većom gustinom sadnje.

Zahvalnica

Istraživanja u ovom radu su deo projekta TR31063 koji finansira Ministarstvo prosvete, nauke i tehnološkog razvoja Republike Srbije.

Literatura

Blažek, J., & Pištěková, I. (2012). Final evaluation of nine plum cultivars grafted onto two rootstocks in a trial established in 1998 at Holovousy. *Horticultural Science*, *39*, 108-115.

Botu, I., Achim, G., Botu, M., Godeanu, I., & Baciu, A. (2002). The evaluation and classification of growth vigor of the plum cultivars grafted on various rootstocks. *Acta Horticulturae*, 577, 299-306.

Glišić, I., Cerović, R., Milošević, N., Đorđević, M., & Radičević, S. (2012). Initial and final fruit set in some plum (*Prunus domestica* L.) hybrids under different pollination types. *Genetika*, *44*, 583-593.

Glišić, I.P., Milošević, T., Glišić, I.S., Ilić, R., Paunović, G., & Milošević, N. (2016). Tree vigour and yield of plum grown under high density planting system. *Acta Horticulturae*, 1139, 131-136.

Grzyb, S.Z., & Sitarek, M. (2006). The influence of different rootstocks on the growth, yield and fruit quality of plum tree cv. 'Dąbrowice Prune' planted in exhausted soil. *Sodininkystė ir Daržininkystė*, *25*, 292-295.

Hrotkó, K., Magyar, L., Simon, G., & Klenyán, T. (2002). Effect of rootstocks on growth and yield efficiency of plum cultivars. *Acta Horticulturae*, 577, 105-110.

Jaćimović, V., Radović, M., Bogavac, M., & Božovic, Đ. (2012). Impact of honey bees (*Apis mellifera* L.) on pollination and yield of cultivated plum varieties. *Agriculture and Forestry*, *58*, 151-157.

Kosina, J. (2004). Orchard performance of two plum cultivars on some clonal rootstocks. *Horticultural Science*, *31*, 93-95.

Magyar, L., & Hrotkó, K. (2006). Growth and productivity of plum cultivars on various rootstocks in intensive orchard. *International Journal of Horticultural Science*, *12* (3), 77-81.

Meland, M. (2010). Performance of six European plum cultivars on four plum rootstocks growing in a northern climate. *Acta Agriculturae Scandinavica Section B – Soil and Plant Science*, *60*, 381-387.

Mészáros, M., Kosina, J., Laňar, L., & Náměstek, J. (2015). Long-term evaluation of growth and yield of Stanley and Cacanska lepotica plum cultivars on selected rootstocks. *Horticultural Science*, *42*, 22-28.

Milatović, D., Zec, G., Đurović, D., Boškov, Đ., & Radović, M. (2018). Evaluation of early plum cultivars in the region of Belgrade (Serbia). *IX International Scientific Agriculture Symposium "Agrosym 2018"* (pp. 612-617). Jahorina, Bosnia and Herzegovina.

Milošević, T., & Milošević, N. (2012). The physical and chemical attributes of plum influenced by rootstock. *Acta Alimentaria*, *41*, 293-303.

Nikolić, D., & Milatović, D. (2010). Examining self-compatibility in plum (*Prunus domestica* L.) by fluorescence microscopy. *Genetika*, *42*, 387-396.

Nikolić, D.T., Rakonjac, V.S., & Fotirić-Akšić, M.M. (2012). The effect of pollenizer on the fruit set of plum cultivar Čačanska Najbolja. *Journal of Agricultural Sciences*, *57*, 9-18.

Neumüller, M. (2011). Fundamental and applied aspects of plum (*Prunus domestica* L.) breeding. *Fruit, Vegetable and Cereal Science and Biotechnology*, *5* (spec. issue 1), 139-156.

Ogašanović, D., Miletić, R., & Mitrović, M. (2011). Uporedna ispitivanja različitih vegetativnih podloga za šljivu. *Arhiv za poljoprivredne nauke*, *72*, 45-54.

Radović, M., Milatović, D., & Zec, G. (2016). Influence of rootstocks on the properties of fruiting twigs in plum cultivars. *VII International Scientific Agriculture Symposium,"Agrosym 2016"* (pp. 839-844). Jahorina, Bosnia and Herzegovina.

Rato, A.E., Agulheiro, A.C., Barroso, J.M., & Riquelme, F. (2008). Soil and rootstock influence on fruit quality of plums (*Prunus domestica* L.). *Scientia Horticulturae*, *118*, 218-222.

Reig, G., i Forcada, C.F., Mestre, L., Jiménez, S., Betrán, J.A., & Moreno, M.Á. (2018). Horticultural, leaf mineral and fruit quality traits of two 'Greengage' plum cultivars budded on plum based rootstocks in Mediterranean conditions. *Scientia Horticulturae*, *232*, 84-91.

Republički zavod za statistiku (2018). Datum pristupa: 30.12.2018. http://www.stat.gov.rs/

Sitarek, M., Grzyb, Z.S., Guzowska-Spaleniak, B., & Lis, J. (2004). Performance of three rootstocks for plums in two different soils and climatic conditions. *Acta Horticulturae*, 658, 273-277.

Sosna, I. (2002). Growth and cropping of four plum cultivars on different rootstocks in South Western Poland. *Journal of Fruit and Ornamental Plant Research*, *10*, 95-103.

Surányi, D. (2006). Estimation of plum and prune cultivars with morphogenetic traits. *International Journal of Horticultural Science*, *12* (2), 147-152.

Primljeno: 5. januara 2019.
Odobreno: 15. maja 2019.

THE INFLUENCE OF ROOTSTOCKS ON THE GROWTH, YIELD AND FRUIT QUALITY OF THE PLUM CULTIVAR ČAČANSKA RANA

Dragan P. Milatović[1*], Mirjana M. Radović[2], Gordan N. Zec[1] and Đorđe D. Boškov[1]

[1]University of Belgrade, Faculty of Agriculture,
Nemanjina 6, 11080 Belgrade – Zemun, Serbia
[2]University of East Sarajevo, Faculty of Agriculture,
Vuka Karadžića 30, 71123 East Sarajevo, Bosnia i Herzegovina

A b s t r a c t

The paper examines the influence of three clonal rootstocks (ʻPixy', ʻFereley' and ʻSt. Julien A') along with seedlings of Myrobalan (control) on the growth, yield and fruit quality of the plum cultivar ʻČačanska Rana'. Research was conducted in the area of the Belgrade Danube basin for the six-year period (2013–2018). In comparison to control, all three clonal rootstocks have shown a significant effect on the decrease of vigor expressed as a trunk cross-sectional area. The lowest vigor was found in trees on the ʻPixy' rootstock, then on ʻFereley' and ʻSt. Julien A' rootstocks. Regarding the rootstocks ʻFereley' and ʻSt. Julien A', significantly higher fruit set and yields were achieved in comparison to control. Clonal rootstocks induced an increase in the yield per hectare ranging from 72% to 93% compared to Myrobalan. The highest yield efficiency was found in the trees on the ʻFereley' rootstock, followed by the yields observed in the trees on the ʻPixy' and ʻSt. Julien A' rootstocks. Significantly higher fruit weight compared to control was obtained in the trees on the ʻFereley' rootstock. Rootstocks did not show any significant effect on the soluble solids and total acid contents of the fruit. Based on the results obtained, it can be concluded that all three clonal rootstocks showed better results than Myrobalan, and can be recommended for establishing intensive plum plantations with higher planting density. The best results in terms of yield and fruit quality were obtained with the ʻFereley' rootstock.

Key words: *Prunus domestica*, clonal rootstocks, vigor, yield, fruit quality.

Received: January 5, 2019
Accepted: May 15, 2019

[*]Corresponding author: e-mail: mdragan@agrif.bg.ac.rs

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 175-188

https://doi.org/10.2298/JAS1902175M
UDC: 664.844:577.16
634.1/.7-156.3
Original scientific paper

VITAMIN AND PROVITAMIN PROFILES OF SELECTED VEGETABLES AS AFFECTED BY STORAGE AND DIFFERENT DRYING METHODS

Aderonke O. Mosuro and Olugbenga A. Ogunwole*

Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria

Abstract: Effects of drying methods on the vitamin and provitamin compositions of selected vegetables during storage were assessed in this study. *Telfaria occidentalis*, *Celosia argentea* (green), *Vernonia amygdalina*, *Moringa oleifera*, *Launaea taraxacifolia, Curcubita maxima* and *Celosia argentea* (red) were subjected to air drying (AD), oven drying (OD) and freeze drying (FD). The experiment was a 3x7 factorial arrangement in a completely randomized design. Dried leaves were milled and assayed for vitamins (pyridoxine, riboflavin, ascorbic acid and tocopherol) and provitamins (total carotene and ergocalciferol). Samples were stored in opaque airtight containers after drying and assayed periodically at weeks 0, 3, 6, 9, 12, 15 and 18 of storage. Air-dried samples had significantly higher ($P<0.05$) total carotene (1177.49 µg/100g), pyridoxine (0.59 mg/100g), riboflavin (0.46 mg/100g), ascorbic acid (39.11 mg/100g), ergocalciferol (46.55 µg/100g) and tocopherol (57.52 µg/100g) compared with samples dried by other methods. *Moringa oleifera* leaf type had significantly higher ($P<0.05$) total carotene (1079.48 µg/100g), riboflavin (0.41 mg/100g), ergocalciferol (46.40 µg/100g) and α-tocopherol (58.45 µg/100g) while *Cucurbita maxima* had significantly higher ($P<0.05$) pyridoxine (0.73 mg/100g). Effects of the interaction of drying methods and leaf type were significant ($P<0.05$) on the vitamin and provitamin compositions of samples. The effect of the interaction of the oven drying method and leaf type was highly significant ($P<0.05$) on inherent vitamin and provitamin of samples. Vitamin and provitamin compositions of samples were stable until week six. Air-dried samples contained more vitamins and provitamins which were also more retained in storage.

Key words: dried leaves, phytonutrient profile, vitamin/provitamin assays, drying methods, storage duration.

*Corresponding author: e-mail: oluogunwole@yahoo.com

Introduction

Green vegetables are a rich source of nutrients for animals (Rickman et al., 2007). In an environment where there is the increasing challenge of getting alternative feedstuffs, there is a need to explore ways of preserving green vegetables which are ubiquitous and often available all year round (Voster Ineke et al., 2007). Drying is a method that provides a simple manageable way of preserving leafy vegetables. Freeze drying was initially proposed as the best method of preserving local green vegetables, but Lee and Labuza (1975) reported that this method heavily reduced the levels of ascorbic acid in the vegetables. There are several communities in the developing world where freezers are not available, so the drying method that will be adopted should be the one that offers good potential by ensuring that nutrients can be preserved as much as possible.

Leafy vegetables contain vitamins and minerals which could contribute greatly to dietary provision for normal growth and protection against diseases (Achikanu et al., 2013). Phytonutrient-rich leafy vegetables and plants are available in the tropics (Akoroda, 1990; Oluwole et al., 2003; Achikanu et al., 2013) with viable potentials as dietary sources of vitamins and minerals. One of the main limitations to the use of green leaves as alternative nutritional additive for livestock and poultry is the innate moisture content and the challenges of its removal without damaging the valuable phytochemicals.

Most green vegetables are seasonal, and drying methods help in their preservation by reducing the high moisture contents (Naikwade et al., 2012). The consideration of the effects of drying methods are, therefore, very crucial because of their critical implications on phytonutrients and the residual phytochemicals of dried leaves, as well as the stability of the nutrients.

There is scanty information on the retention of vitamins by plants and green leafy vegetables when subjected to different drying methods and also how long the retained vitamins and provitamins would remain stable in storage. This research was therefore aimed at evaluating the effects of three different drying methods on vitamin and provitamin profiles of seven different vegetable leaves, as well as the stability of their inherent nutrients during storage.

Materials and Methods

The experiment was carried out at the Central Laboratory, Department of Animal Science, University of Ibadan, Ibadan, Nigeria. Seven vegetables assessed were: fluted pumpkin (*Telfairia occidentalis*); African wild lettuce (*Launaea taraxacifolia*); African spinach – green (*Celosia argentea*); gourd melon pumpkin (*Curcubita maxima*); African spinach – red (*Celosia argentea*); moringa leaves

(*Moringa oleifera*) and bitter leaf (*Vernonia amygdalina*). Freeze drying, air drying and oven drying at 55 ^{o}C were the methods of drying.

Freeze drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. The leaves were separated from the stems of plant samples, washed with de-ionised water and drained before storing in a freezer at 20^{o}C before transfer to a freeze dryer. Freeze-dried samples were ground to fine powder for immediate analyses. The portion of the freeze-dried sample was stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

Oven drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. Leaf samples were cleaned with de-ionised water, drained, weighed and placed in the Gallenkamp BS 300 electric oven with the fan automatically regulated and the temprature set at 55^{o}C. Samples were turned at eight-hour intervals until dried to a constant weight which was achieved at 18 hours of drying. The leaves were then put in a desiccator and reweighed after cooling before grinding to fine powder for immediate analyses. The sample was thereafter stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

Air drying: Fresh leaves were plucked at six weeks of plant growth or regrowth in the case of moringa. Leaf samples were cleaned with de-ionised water, drained, blotted dry with absorbent paper and spread inside perforated plastic trays placed indoors on tables to dry at room temperature to a constant weight while turning the samples regularly at six-hour intervals for a total period of 72 hours. The leaves were then weighed and milled to powder for analyses at once. The sample was thereafter stored in an opaque airtight container and analysed at weeks 3, 6, 9, 12, 15 and 18, respectively. All analyses were done in triplicate.

The phytochemical assay for total carotene pyridoxine, riboflavin, ascorbic acid, tocopherol and ergocalciferol in the samples was conducted according to AOAC (2000).

Data analyses

Data were subjected to analysis of variance (SAS 2000) and means were separated at $\alpha_{0.05}$ using the Duncan's option of the same software.

Results and Discussion

The main effects of drying methods on vitamin and provitamin indices are shown in Table 1. There were significant variations ($P<0.05$) in vitamin and provitamin profiles of the vegetables due to different drying methods. The air drying method had the least effect on residual phytochemicals with significantly higher ($P<0.05$) levels of 1177.49 µg/100g total carotene, 0.59 mg/100g pyridoxine, 0.46 mg/100g riboflavin, 39.11 mg/100g ascorbic acid, 46.55 μg/100g ergocalciferol and 57.52 μg/100g α-tocopherol. The highest impact on vitamin and provitamin parameters was observed in oven-dried samples with significantly lower (P<0.05) compositions of 936.97 μg/100g total carotene, 0.39 mg/100g pyridoxine, 0.22 mg/100g riboflavin, 23.06 mg/100g ascorbic acid, 35.42 μg/100g and 44.07 μg/100g α-tocopherol. This observation was in agreement with reports that the air drying method preserved higher amounts of vitamins in green leafy vegetables (Lakshi and Vimala, 2000; Krokida and Maroulis, 2007; Saga and Suresh, 2010; Naikwade, 2014), but was contrary to the report of Negi and Roy (2000) that oven drying at low temperature had the least effect on the innate nutrient composition of vegetables. The report from this study is also in agreement with the findings of Kiremire et al. (2010) that oven drying caused higher nutrient losses.

The freeze drying method was earlier reported (Krokida and Maroulis, 2007) to cause higher porosity in freeze-dried plant materials than air drying which may be the reason for its higher impact on inherent nutrients compared with air drying. The loss of crispness of vegetables and their nutrients when freeze-dried was documented (Onayemi and Badifu, 1987). This was attributed to freeze-thaw damage syndrome which has the largest impact on the loss of inherent nutrients. Findings in this study were also at variance with those of Oladele and Aborisade (2009) that air drying resulted in the greatest loss of ascorbic acid in vegetables. The levels of 40.097mg/100g ascorbic acid in *Telfaria occidentalis* in this study was higher than 35.97 mg/100g documented by Ukegbu and Okereke (2013) in *Vernonia amygdalina*. The observations for other phytochemicals conformed to the findings of Nangula et al. (2010) although the riboflavin content obtained in this study was higher.

Table 1. The main effect of drying methods on the vitamin composition of dried vegetable leaves.

Drying method	Total carotene (μg/100g)	Pyridoxine (mg/100g)	Riboflavin (mg/100g)	Ascorbic acid (mg/100g)	Ergocalciferol (μg/100g)	Tocopherol (μg/100g)
Air drying	1177.49^{a}	0.59^{a}	0.46^{a}	39.11^{a}	46.55^{a}	57.52^{a}
Oven drying	936.97^{c}	0.39^{c}	0.22^{c}	23.06^{c}	35.42^{c}	44.07^{c}
Freeze drying	971.37^{b}	0.56^{b}	0.39^{b}	34.18^{b}	44.79^{b}	53.38^{b}
SEM	3.50	0.01	0.004	0.24	0.26	0.24

Means with different superscripts in the same columns are significantly different (P<0.05); SEM – Standard error of the means.

Findings in this study showed that air drying was the least invasive method out of the three methods of drying. Although the freeze drying method was conducted also at a very low temperature, the effect of freezing and moisture extraction would cause leaves to break and become porous, resulting in higher losses of the inherent nutrients. Vitamins in naturally sourced materials such as green leafy vegetables are highly labile and heat sensitive (Sablani, 2006). The subjection of vegetable leaves to heat at a temperature as low as 55^{o}C will still affect the inherent vitamins, leading to significant losses as observed in this study. Sablani (2006) earlier reported that drying of vegetables nowadays was not only based on prolonging shelf life, but also on the retention of the nutritive value and flavour.

The main effect of leaf type on vitamin and provitamin parameters is shown in Table 2. *Cucurbita maxima* had the highest (P<0.05) level of pyridoxine with 0.73 mg/100g and the least was 0.38 mg/100g in *Celosia argentea* (green), which was significantly lower than 0.52 mg/100g in red *Celosia argentea*. *Moringa oleifera* (0.42 mg/100g pyridoxine, 0.41 mg/100g riboflavin, 39.61 mg/100g ascorbic acid, 58.45 µg/100g α-tocopherol, 1079.48 µg/100mg total carotene and 46.40 µg/100g ergocalciferol) and *Vernonia amygdalina* (0.46 mg/100g pyridoxine, 0.40 mg/100g riboflavin, 38.68 mg/100g ascorbic acid, 47.33 µg/100g α-tocopherol, 1072.70 µg/100mg total carotene and 47.02 µg/100g ergocalciferol) had the overall highest (P<0.05) retention of vitamin and provitamin contents among leaf types.

Table 2. The main effect of leaf type on the vitamin composition of dried vegetable leaves.

Vitamin parameters	TO	CA (green)	VA	MO	LT	CM	CA (red)	SEM
Pyridoxine (mg/100g)	0.54^{b}	0.38^{f}	0.46^{d}	0.42^{e}	0.55^{b}	0.73^{a}	0.52^{c}	0.01
Riboflavin (mg/100g)	0.36^{c}	0.38^{b}	0.40^{a}	0.41^{a}	0.26^{e}	0.29^{d}	0.26^{e}	0.01
Ascorbic acid (mg/100g)	40.10^{a}	32.35^{c}	38.68^{b}	39.61^{a}	23.81^{e}	26.10^{d}	24.18^{e}	0.36
α-Tocopherol (µg/100g)	50.06^{d}	52.63^{c}	47.33^{f}	58.45^{a}	55.03^{a}	48.17^{e}	49.96^{d}	0.37
Total carotene (µ/100g)	1059.45^{b}	1056.11^{b}	1072.70^{a}	1079.48^{a}	982.44^{c}	958.14^{d}	991.96^{c}	5.34
Ergocalciferol (µ/100g)	40.66^{c}	39.93^{c}	47.02^{a}	46.40^{a}	41.70^{b}	38.25^{d}	41.82^{b}	0.40

Means with different superscripts along the same row are significantly different (P<0.05). SEM – Standard error of the means; TO – *Telfaria occidentalis*; CA(g) – *Celosia argentea* green variety, VA – *Vernonia amygdalina*, MO – *Moringa oleifera*, CM – *Cucurbita maxima*, CA (red) – *Celosia argentea* red.

The green *Celosia argentea* had significantly higher (P<0.05) total carotene, riboflavin, ascorbic acid and tocopherol compared with the red variety which contained higher (P<0.05) pyridoxine and ergocalciferol only. The total carotene of 958.14 µg/100g in *Cucurbita maxima* was lower than 13520 µg/100g as reported by Sahabi et al. (2012). The 32.35 mg/100g ascorbic acid in *Celosia argentea* (green) was lower than 42.1 mg/100g as reported by Mensah et al. (2008).

Leaf type as well as the drying method affected vitamin and provitamin compositions of vegetable leaves. This is in agreement with the findings of Oduro et al. (2008) that the nutrient composition of *Moringa oleifera* leaves differed significantly from that of *Ipomoea batatas*. The differences observed in this study may be due to differences in the species of the selected vegetables. The differences in variety where the leaves were of similar species were also implicated in the differences observed in this study. This observation is particularly true for the two varieties of *Celosia argentea* which had significant differences (P<0.05) in their inherent vitamin and provitamin compositions. Oduro et al. (2008) also reported differences in the nutrient composition of seven different varieties of *Ipomoea batatas* leaves. The findings in this study strongly indicate that different varieties of the same species of vegetable would not connote the same nutrient content.

Effects of the interaction of drying methods and leaf type on vitamin and provitamin compositions of the selected vegetable leaves are shown in Table 3. The inherent vitamin and provitamin profiles significantly varied (P<0.05) with the method of drying. *Cucurbita maxima* contained 0.91 mg/100g, 0.84 mg/100g and 0.43 mg/100g pyridoxine in freeze-, air- and oven-dried samples, respectively. Most of the samples followed this trend with significant differences in their vitamin and provitamin compositions as a result of the different drying methods. However, α-tocopherol compositions in air- and freeze-dried *Telfaria occidentalis* were similar (P>0.05) to 55.28 and 54.75 µg/100g, respectively. Effects of the interaction of drying methods and leaf type also resulted in similar (P>0.05) composition of ergocalciferol in air-dried *T. occidentalis* (44.48 µg/100mg), and green *C. argentea* (44.98 µg/100mg) freeze-dried *T. occidentalis* (43.94 mg/100g) and air-dried *Cucurbita maxima* (45.81 mg/100g) significantly differed (P<0.05) from each other, but both were also similar (P>0.05) to air-dried *T. occidentalis* and green *C. argentea*. Riboflavin concentration was higher (P<0.05) in air-dried *Telfaria occidentalis* (0.56 mg/100g) compared with other treatments. The observation differed in *Launea taraxacifolia* where higher riboflavin concentration (P<0.05) was 0.43 mg/100g in freeze-dried samples and lower (P<0.05) 0.20 and 0.17 mg/100g were found in air- and freeze-dried *L. taraxacifolia*, respectively.

Table 3. Effects of interaction of drying methods and leaf types on vitamin and provitamin indices of selected leafy vegetables.

DM	LT	Pyridoxine (mg/100g)	Riboflavin (mg/100g)	Ascorbic acid (mg/100g)	α-tocopherol (μg/100g)	Total carotene (μg/100g)	Ergocalciferol (μg/100g)
AIR DRYING	1	0.79[c]	0.56[a]	45.09[a]	55.28[d]	1238.78[b]	44.48[ef]
	2	0.41[ml]	0.52[b]	42.56[b]	58.54[c]	1219.07[c]	44.98[ef]
	3	0.55[g]	0.50[b]	44.62[a]	55.49[d]	1264.78[a]	51.82[b]
	4	0.42[kl]	0.51[b]	45.43[a]	62.01[a]	1239.42[b]	51.07[b]
	5	0.51[h]	0.20[i]	20.14[j]	60.54[b]	928.86[fgh]	47.58[d]
	6	0.84[b]	0.44[c]	37.37[f]	59.36[bc]	1129.54[d]	45.81[e]
	7	0.61[f]	0.45[c]	38.58[def]	51.43[f]	1122.04[bc]	40.14[h]
OVEN DRYING	1	0.47[ij]	0.32[g]	34.13[g]	40.15[i]	994.69[e]	33.56[k]
	2	0.35[op]	0.31[g]	15.82[l]	44.23[h]	1007.97[e]	32.53[kl]
	3	0.38[mn]	0.32[fg]	33.95[g]	36.64[j]	1008.96[e]	41.03[gh]
	4	0.34[p]	0.34[f]	34.44[g]	53.09[e]	999.96[e]	38.57[i]
	5	0.45[kj]	0.17[j]	17.09[l]	49.52[g]	886.56[i]	35.08[j]
	6	0.43[kl]	0.03[l]	14.69[l]	44.74[h]	831.00[j]	35.33[j]
	7	0.29[q]	0.07[k]	11.30[m]	40.15[i]	829.65[j]	31.82[l]
FREEZE DRYING	1	0.37[no]	0.21[i]	41.07[c]	54.75[d]	944.91[f]	43.94[f]
	2	0.36[no]	0.31[g]	38.66[de]	55.11[d]	941.30[fg]	42.29[g]
	3	0.46[j]	0.38[e]	34.48[ef]	49.87[g]	944.35[f]	48.23[cd]
	4	0.49[hi]	0.38[e]	41.06[d]	60.24[b]	999.07[e]	49.55[c]
	5	0.70[d]	0.43[cd]	34.19[g]	55.03[d]	1131.92[d]	42.43[g]
	6	0.91[a]	0.41[d]	26.25[h]	40.41[i]	913.87[h]	33.61[k]
	7	0.66[e]	0.25[h]	22.67[i]	58.29[c]	924.20[gh]	53.50[a]
SEM		0.02	0.01	0.63	0.64	9.26	0.70

Means with different superscripts along the same column are significantly different (P<0.05); SEM – Standard error of the means, 1 – *Telfaria occidentalis*, 2 – *Celosia argentea* (green), 3 – *Vernonia amygdalina*, 4 – *Moringa oleifera*, 5 – *Launea taraxacifolia*, 6 – *Curcubita maxima*, 7 – *Celosia argentea* (red); DM – Drying methods, LT – Leaf type.

Observations so far from this study support the earlier reports (Kiremire et al., 2010; Ukegbu and Okereke, 2013) that oven drying results in more significant loss of inherent vitamin and provitamin contents compared with air or freeze drying. It also corroborates the assertion that the air drying method had the least destructive effect on inherent nutrients in most of the vegetable leaves.

The effect of the relationship between drying methods and duration of storage on the pyridoxine composition of samples is shown in Figure 1. The regression curve indicated that the optimum levels of 0.59 and 0.39 mg/100g pyridoxine were in air-dried and oven-dried samples at week six, respectively. Prolonged storage resulted in significant reductions in the pyridoxine content of samples from week nine. In Figure 1, freeze-dried samples with 0.57 mg/100g pyridoxine at week 6 declined to 0.24 mg/100g at week 18 of storage. The effect of the drying methods during storage on pyridoxine compositions resulted in the expressed quadratic equations 1, 2 and 3 below with the highly significant and positive R^2 values of

0.9969, 0.9785 and 0.9898, respectively. It was surmised that the levels of pyridoxine composition were strongly dependent on the duration of storage irrespective of the drying method used.

$Y = -0.0123x^2 + 0.0469x + 0.5517$ ($R^2 = 0.9969$) (air-dried samples) …………. (1)

$Y = -0.0094x^2 + 0.0234x + 0.5574$ ($R^2 = 0.9785$) (freeze-dried samples) ………. (2)

$Y = -0.0081x^2 + 0.021x + 0.3768$ ($R^2 = 0.9898$) (oven-dried samples) ……..….. (3)

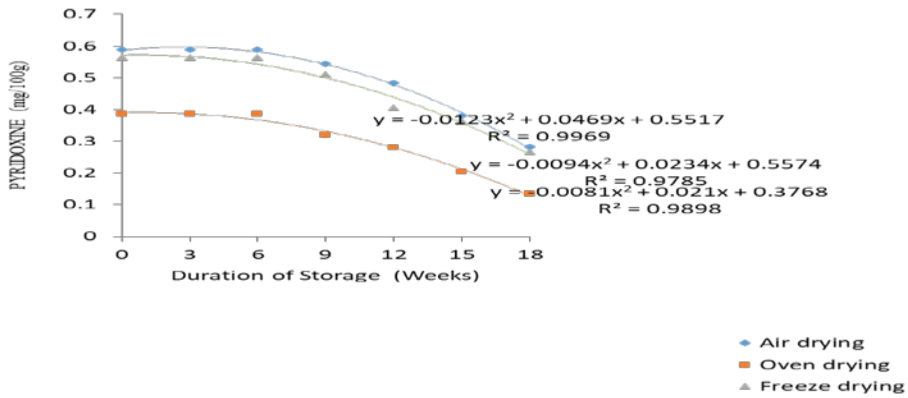


Figure 1. The effects of the relationship between drying methods and storage duration on the pyridoxine composition (mg/100g) of selected leaves.

The effect of the relationship between storage duration and drying methods on the riboflavin composition of vegetable is shown in Figure 2. The regression curves show that optimum concentrations of 0.47, 0.35 and 0.24 mg/100g riboflavin were attained at week six from air-, freeze- and oven-dried samples, respectively. Longer duration beyond week six of storage significantly reduced ($P<0.05$) the riboflavin concentration of dried samples. The determination factors (R^2) are shown in Equations 4, 5 and 6 below:

$Y = -0.0082x^2 + 0.0271x + 0.4386$ ($R^2 = 0.9711$) (air-dried samples) ………….. (4)

$Y = -0.0049x^2 + 0.0091x + 0.3407$ ($R^2 = 0.9785$) (freeze-dried samples) ………. (5)

$Y = -0.0034x^2 + 0.004x + 0.2263$ ($R^2 = 0.9729$) (oven-dried samples) ……..…. (6)

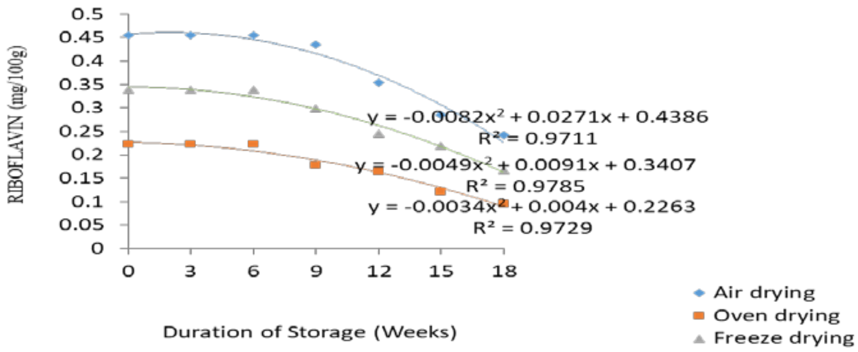


Figure 2. The effects of the relationship between storage duration and drying methods on the riboflavin composition of leaves (mg/100g).

The ascorbic acid compositions of selected vegetable leaves as affected by the drying methods in the duration of storage are shown in Figure 3. An optimum concentration of 36 mg/100g ascorbic acid was observed in freeze-dried leaves.

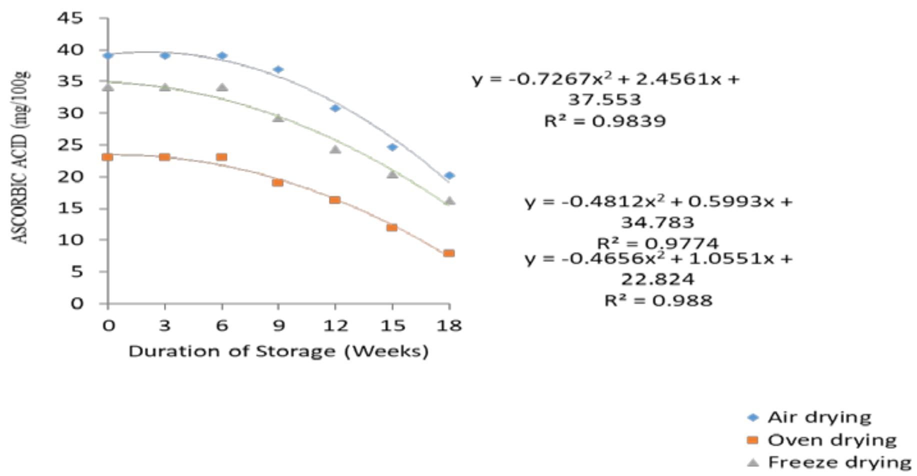


Figure 3. The effects of the relationship between drying methods and storage duration on the ascorbic acid composition (mg/100g) of selected leaves.

The regression equations for the different drying methods indicated strong and positive relationships between the ascorbic acid composition and the storage duration. The longer the duration of storage, the more rapid the decline. The determination factors (R^2) for ascorbic acid are shown in Equations 7, 8 and 9 below:

$Y = -0.7267x^2 + 2.4561x + 37.553$ ($R^2 = 0.9839$) (air-dried samples) …........…. (7)
$Y = -0.4812x^2 + 0.5993x + 34.783$ ($R^2 = 0.9774$) (freeze-dried samples) …........ (8)
$Y = -0.4656x^2 + 1.0551x + 22.824$ ($R^2 = 0.9880$) (oven-dried samples) ……....... (9)

The effects of the relationships between drying methods and duration of storage on the α-tocopherol composition of selected vegetables are shown in Figure 4. The optimal α-tocopherol compositions of 52.50, 59.00 and 0.46 µg/100mg were obtained at week six of storage in freeze-, air- and oven-dried samples, respectively. The regression equations were highly significant ($P<0.05$) and the relationships were quadratic for all dried samples during storage. The relationships are as shown in Equations 10, 11 and 12 below:

$Y = -1.0156x^2 + 3.7906x = 54.736$ ($R^2 = 0.9809$) (air-dried) ………................... (10)
$Y = -0.7134x^2 + 0.7635x + 54.514$ ($R^2 = 0.9731$) (freeze-dried) …….......……. (11)
$Y = -0.805x^2 + 1.5972x + 44.084$ ($R^2 = 0.9791$) (oven-dried) ……...........…… (12)

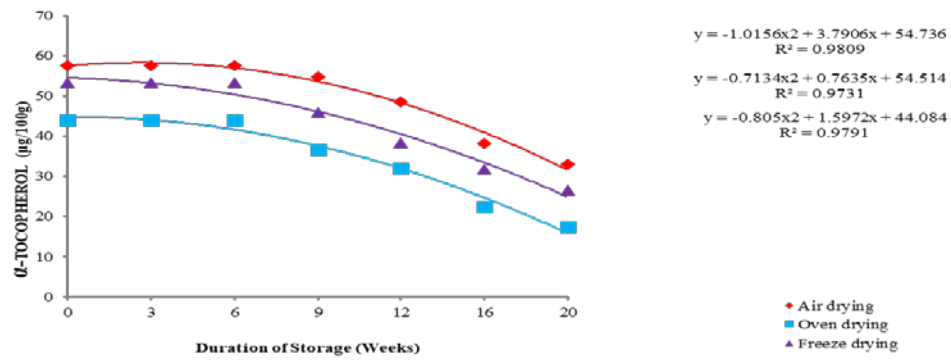


Figure 4. The effects of the relationship between storage duration and drying methods on the α-tocopherol composition (µg/100g) of selected vegetable samples.

The effects of the relationships between drying methods and duration of storage on the total carotene composition of selected vegetables are shown in Figure 5. The regression curves showed optimum concentrations of 960, 1000 and 1200 µg/100g, respectively were obtained in oven-, freeze- and air-dried samples in zero to week six of storage. A significant decline ($P<0.05$) in the total carotene concentration was observed as storage duration increased. Highly significant determination factors were recorded for air-dried (0.93), oven-dried (0.98) and freeze-dried (0.98) samples as shown in Equations 13, 14 and 15 below.

$Y = -13.694x^2 + 25.945x + 1211.8$ ($R^2 = 0.9282$) (air-dried samples) ……..…. (13)

$Y = -16.015x^2 + 37.997x + 963.28$ ($R^2 = 0.9763$) (air-dried samples) ……...... (14)

$Y = -17.925x^2 + 40.598x + 928.07$ ($R^2 = 0.9847$) (air-dried samples) ……….... (15)

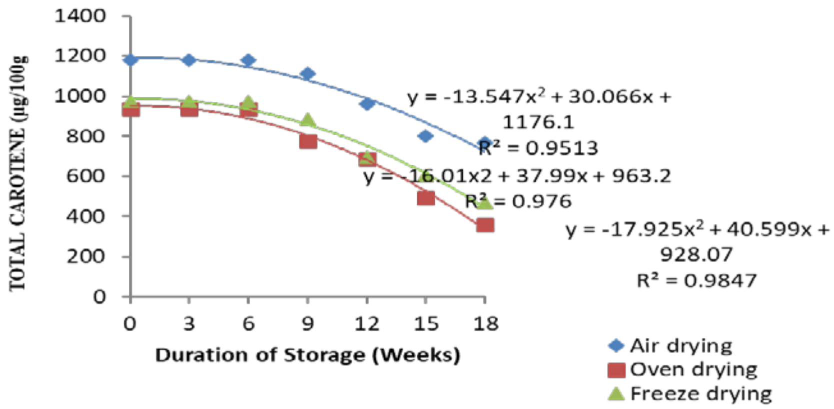


Figure 5. The effects of the relationship between drying methods and storage duration on the total carotene compositions (µg/100g) in selected vegetable samples.

The ergocalciferol compositions of selected vegetables as influenced by drying methods and duration of storage are shown in Figure 6. Longer duration of storage resulted in a significant decline of ergocalciferol from week six of storage irrespective of the drying methods. The optimal ergocalciferol concentrations of 36.03, 44.00 and 47.82 µg/100g were obtained at week six for oven-, freeze- and air-dried vegetable samples, respectively. The regression was highly significant ($P<0.05$) and the quadratic relationships as shown in Equations 16, 17 and 18 below indicated that ergocalciferol compositions of the stored samples diminished rapidly after week six of storage.

$Y = -0.7273x^2 + 2.5965x + 44.768$ ($R^2 = 0.9827$) (air-dried samples) ……..…. (16)

$Y = -0.6824x^2 + 1.3118x + 44.929$ ($R^2 = 0.9791$) (air-dried samples) ……..…. (17)

$Y = -0.6625x^2 + 1.4476x + 35.204$ ($R^2 = 0.9812$) (air-dried samples) ……..…. (18)

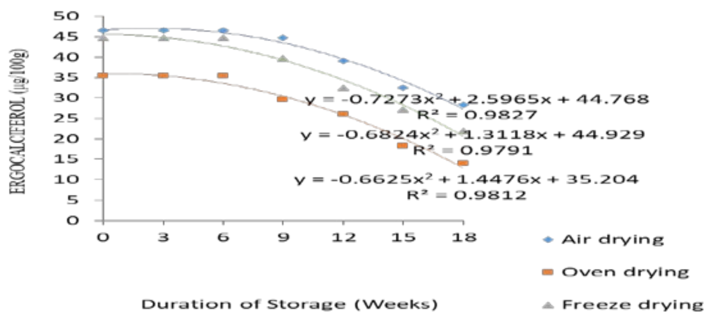


Figure 5. The effects of the relationship between storage duration and drying methods on total carotene (µg/100g).

The regression analysis showed a high level of stability for a period that is comparable with industry standards recommended for efficacy of vitamins in commercial proprietary vitamin and mineral premixes. There were significant differences ($P<0.05$) across the board on the basis of storage. All values observed were stable for up to 9 weeks, and a decline was observed in all drying methods from week 9 at which point the samples began to lose their inherent nutrient stability. The equations highlighted for the air-, oven- and freeze-dried samples gave R^2 values which indicated strong and positive relationships, showing that vitamin and provitamin concentrations were strongly dependent on the storage period irrespective of the drying method.

Conclusion

Air, oven and freeze drying methods preserved the vitamins and provitamins of selected green vegetables. However, air drying had the least effect on the innate vitamin and provitamin of dried vegetables followed by freeze drying and the least effective method of drying for vitamin retention was oven drying. Even in storage, air drying proved the most effective in retaining the vitamins of all the selected vegetables.

References

Akoroda, M.O. (1990). Ethnobotany of *Telfaria occidentalis* (*Cucurbitaceae*) among Igbos of Nigeria. *Economic Botany, 44* (1), 29-39.

Achikanu, C.E., Eze-Steven, P.E., Ude, C.M., & Ugwuokolie, O.C. (2013). Determination of the vitamin and mineral composition of common leafy vegetables in south eastern Nigeria. *International Journal of Current Microbiology and Applied Science, 2* (11), 347-353.

AOAC (2005). *Official method of analysis* (18^{th} ed.) Washington DC: Association of Official Analytical Chemists.

Kiremire, B.T., Musinguzi, E., & Kikafunda, J.K. (2010). Effects of vegetable drying techniques on nutrient content: a case study of south-western Uganda. *African Journal of Food, Agriculture, Nutrition and Development, 10* (5), 1-6.

Krokida, M.K., & Maroulis, Z.B. (2007). Effect of drying method on shrinkage and porosity. *Journal of Drying Technology, 15* (10), 2441-2458.

Lakshi, V., & Vimala, V. (2000). Nutritive value of green leafy vegetables. *Journal of Food Science and Technology, 37* (5), 465-471.

Lee, S.H., & Labuza, T.P. (1975). Destruction of ascorbic acid as a function of water activity. *Journal of Food Science, 40* (2), 370-373.

Mensah, J.K, Okoli, R.I., Ohaju-Obodo, J.O., & Eifediyi, K. (2008). Phytochemical, nutritional and Medicinal properties of some leafy vegetables consumed by Edo people of Nigeria. *African Journal of Biotechnology, 7* (14), 2304-2309.

Naikwade, P.V. (2014). Effect of drying methods on nutritional value of some vegetables and chlorophyll retention of leafy vegetables. *Proceeding of the National Conference on Conservation of National Resources and biodiversity for sustainable development,* pp 1-8, Maharashtra, India.

Nangula, P.U., Oelofse, A., Kwaku. G.D., Megan, J.B., & Mieke, F. (2010). Nutritional value of leafy vegetables of sub-saharan Africa and their potential contribution to human health: A review. *Journal of Food composition and analysis, 23* (2010), 499-509.

Negi. P.S., & Roy, S.K. (2000). Effect of blanching and drying methods on β-carotene, ascorbic acid and chlorophyll retention of leafy vegetables. *LWT-Food Science and Technology, 33* (4), 295-298.

Oladele, O.O., & Aborisade, A.T. (2009). Influence of different drying methods and storage on the quality of Indian Spinach (*Basella alba*). *American Journal of Food Technology, 4,* 66-70

Oluwole, F.S., Falode, A.O., & Ogundipe, O.O. (2003). Anti-inflammatory effect of some of Some common Nigerian vegetables. *Nigerian Journal of Physiological Science, 18,* (1-2).

Oduro, I., Ellis, W.O., & Owusu, D. (2008). Nutritional potential of two leafy vegetables: *Moringa oleifera* and *Ipomoea batatas* leaves. *Scientific Research and Essay, 3* (2), 57-60.

Onayemi, O., & Badifu, G.I.O. (1987). Effect of blanching and drying methods on the nutritional and sensory quality of leafy vegetables. *Plant Foods for Human Nutrition, 37* (4), 291-298.

Rickman, Joy. C., Bruhn, Christine. M., & Diane. Barrett, M. (2007). Review: Nutritional comparison of fresh, frozen and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fibre. *Journal of the Science of Food and Agriculture, 87,* 1185-1196.

Sablani, S.S. (2006). Drying of fruits and vegetables: retention of nutritional/functional quality. *Journal of Drying Technology, 24* (2), 123-135.

Sagar, V.R., & Suresh, K.P. (2010). Recent advances in drying and dehydration of fruits and vegetables: a review. *Journal of Food Science and Technology, 47* (15), 10-18.

Voster, Ineke, H.J., van Rensburg J.W., van Zijl J.J., & Venter, S.L. (2007). The Importance of Traditional Leafy Vegetables in South Africa. *African Journal of Food Agriculture, Nutrition and Development, 7* (4), 1-12.

Ukegbu, P.O., & Okereke, C.J. (2013). Effect of solar and sun drying methods on the nutrient Composition and microbial load in selected vegetables. *Sky Journal of Food Science, 2* (5), 35-40.

Received: October 18, 2018
Accepted: May 28, 2019

VITAMINSKI I PROVITAMINSKI PROFILI ODABRANOG POVRĆA USLOVLJENI SKLADIŠTENJEM I RAZLIČITIM METODAMA SUŠENJA

Aderonke O. Mosuro i Olugbenga A. Ogunwole*

Jedinica za poljoprivrednu biohemiju i ishranu, Odsek za stočarstvo, Univerzitet u Ibadanu, Ibadan, Nigerija

R e z i m e

U ovom istraživanju procenjeni su uticaji metoda sušenja na vitaminski i provitaminski sastav odabranog povrća tokom skladištenja. *Telfaria occidentalis, Celosia argentea* (zelena), *Vernonia amygdalina*, *Moringa oleifera*, *Launaea taraxacifolia, Curcubita maxima* i *Celosia argentea* (crvena) bile su podvrgnute sušenju na vazduhu (engl. *air drying* – AD), sušenju u peći (engl. *oven drying* – OD) i sušenju smrzavanjem (engl. *freeze drying* – FD). Ogled je bio trofaktorijalni (3x7), postavljen u potpuno slučajnom planu. Osušeni listovi su samleveni i analizirani radi utvrđivanja sastava vitamina (piridoksin, riboflavin, askorbinska kiselina i tokoferol) i provitamina (ukupni karoten i ergokalciferol). Nakon sušenja uzorci su čuvani u u neprovidnim posudama koje obezbeđuju hermetičnost i ispitivani periodično u 0, 3, 6, 9, 12, 15. i 18. nedelji skladištenja. Uzorci sušeni na vazduhu imali su značajno viši (P<0,05) ukupni karoten (1177,49 µg/100g), piridoksin (0,59 mg/100g), riboflavin (0.46 mg/100g), askorbinsku kiselinu (39,11 mg/100g), ergokalciferol (46,55 µg/100g) i tokoferol (57,52 µg/100g) u poređenju sa uzorcima koji su sušeni drugim metodama. Tip lista biljke *Moringa oleifera* imao je značajno viši (P<0,05) ukupni karoten (1079,48 µg/100g), riboflavin (0,41 mg/100g), ergokalciferol (46,40 µg/100g) i α-tokoferol (58,45 µg/100g), dok je biljka *Cucurbita maxima* imala značajno viši (P<0,05) piridoksin (0,73 mg/100g). Interakcija metoda sušenja i tipa listova značajno je imala uticaj (P<0,05) na vitaminski i provitaminski sastav uzoraka. Interakcija metoda sušenja u peći i tipa listova veoma značajno (P<0,05) je uticala na inherentne vitamine i provitamine u uzorcima. Vitaminski i provitaminski sastav uzoraka bili su stabilni do šeste nedelje. Uzorci sušeni na vazduhu sadržali su više vitamina i provitamina, koji su se takođe zadržali i tokom skladištenja.

Ključne reči: osušeni listovi, profil fitonutrijenata, analiza vitamina/provitamina, metode sušenja, vreme skladištenja.

Primljeno: 18. oktobra 2018.
Odobreno: 28. maja 2019.

*Autor za kontakt: e-mail: oluogunwole@yahoo.com

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 189-201

https://doi.org/10.2298/JAS1902189K
UDC: 635.652(495)
Original scientific paper

FACTORS AFFECTING THE INTEGRATION OF LOCAL TRADITIONAL PRODUCTS INTO QUALITY ASSURANCE SCHEMES

Polyxeni Karagkiozi*, Eleni Oxouzi and Evangelos Papanagiotou

Department of Agricultural Economics, School of Agriculture,
Aristotle University of Thessaloniki, Greece

Abstract: This paper investigates the factors that affect the decisions of the Prespes Beans' (Fassolia 'Prespon') producers to certify their product as a product of protected geographical indication (PGI). The study was based on primary data collected by means of a questionnaire completed by both PGI certified and non-certified producers. The logit model was used for the indication of factors that affect the producers' decision to certify or not to certify their product as PGI. Descriptive statistics were also used for the study of leaders' social features. The research results showed that the producers' decision of adopting the protected geographical indication (PGI) certification was significantly linked to membership producer organizations (cooperatives or other groups), the years of agricultural experience, the size of the cultivated land as well as the motives for joining quality assurance schemes.

Key words: Logit model, local products, beans of Prespes, protected geographical indication, factors.

Introduction

The rising demand for traditional products, which have been lately linked to the healthy diet, has led to the creation of a consumer movement that seeks high-quality products (Panagou et al., 2013). This movement leads to the development of quality assurance schemes to ensure that certain quality standards of different food qualities are met (Hajdukiewicz, 2014). In order to better regulate the origin and the certification of agricultural products, the European Union decided to develop a reputation for high-quality European products, introducing a specific rule system regarding product indications and designations: the protected designation of origin (PDO) label, the protected geographical indication (PGI) label and the traditional specialty guaranteed (TSG) label (Hajdukiewicz, 2014).

Consumers tend to be more interested in identifying products from specific regions of better quality than their competitors (Parrott et al., 2002). Producers'

*Corresponding author: e-mail: xeniakarag@gmail.com

interest in this type of products increases as well (Teuber, 2011) as linking products to specific landscapes, cultural traditions and historical monuments allows for higher prices. Famous local products may also serve as an advertisement for their place of origin since people tend to create positive links between the famous product and its origin. Consequently, tourism flourishes and the area's general development is promoted (Parrott et al., 2002). Thus, increased production and consumption of certified products have become one of the most significant trends of the contemporary market (Parrott et al., 2002).

In Greece, a traditional product that reflects cultural inheritance is the common bean (Trichopoulou et al., 2007). Bean cultivation is very popular in many parts of West Macedonia, especially in the area of Prespes Lakes, where bean is traditionally cultivated (Hellenic Statistical Authority, 2016). Under the pressure of saving and reviving this traditional cultivation (Fassolia Prespon), it was decided by the local Agricultural Cooperative "Pelekanos" to apply for the product registration as a protected geographical indication (PGI) product. The product is nowadays officially registered in the European Union database (European Commission, 2016).

Detailed knowledge about the factors towards this certification scheme is particularly limited for producers. The present paper seeks to fill the research gap by presenting empirical results for the producers of Prespes beans. The cultivation of beans has become one of the most important cultivations of the region both at an economic level and at a social level. It plays a significant role in the local cuisine and can contribute significantly to the improvement of the quality of life and economic well-being of people living in the area. Therefore, the analysis of the factors concerning the adoption of quality assurance schemes is of special interest.

The principle goal of this paper is to identify factors that affect the decisions of the Prespes bean producers to certify their product as a product of protected geographical indication (PGI). The specific objectives of the research reported here are to examine the producers' personal features and attitudes and explore whether the implementation of quality assurance schemes depends on the producers' motives. Therefore, analyzing and studying the producers' personal features, attitudes and motives may encourage further adoption of quality assurance schemes by producers and enhance the socio-economic development of the region.

The European Union by creating the systems known as PDO (Protected Designation of Origin), PGI (Protected Geographical Indication) and TSG (Traditional Specialty Guaranteed) gave positive assistance to producers to help them maximize the advantage they have in quality terms and support their efforts to win the competition (Hajdukiewicz, 2014). Famous 'local/regional products' may create positive links between the place and the product, which consequently may have positive effects on the producers' income and generally on the whole development of the region (Marchini et al., 2014). The integration of local traditional products into quality assurance schemes seems to be an appropriate tool that allows producers to ask for a higher price over the same category products (Hajdukiewicz, 2014). Danezis et al. (2016) discovered that producers by adopting the designation of origin for their products may have positive economic effects, as they lead to a higher retail price and bring in higher financial benefits. The profitability of French Comté cheese can be very well compared with that of its competitors after the adoption of the PDO certification (Sparf, 2010). On the other hand, an empirical study based on the French Brie cheese producers has shown that the adoption of PDO certification is not so attractive as the costs of raw materials get higher, but certified producers benefit from a price premium on their product which offsets their higher production costs (Bouamra-Mechemache & Chaaban, 2010). Although Southern Italy has recently experienced a severe economic crisis, the certified citrus fruits play a significant role because they have become an important and strategic sector of the national economy after the adoption of product designations (Scuderi and Pecorino, 2015). Empirical studies made by Tregear et al. (2007) and Borowska (2010) have shown that local products may be considered as top-quality products and a type of cultural capital, as they provide the opportunity for more social and economic benefits to local rural regions. Similarly, local products may potentially serve as a profitable resource of local development and at the same time they may promote many local particularities through special or geomorphological features that are strongly connected with the area (Tregear et al., 2007; Belletti et al., 2017; Hajdukiewicz, 2014).

As a result, the quality assurance systems were created to promote and protect valuable food names and at the same time enable producers to adapt production to meet consumer demands and expectations, and promote social and economic objectives (e.g., health outcomes and growth in desirable sectors) (Karipidis et al., 2009).

To conclude, all studies published so far prove that certified local traditional products represent a dynamic developing sector where agricultural production is differentiated in terms of quality, by promoting the agricultural local tradition and the socio-economic rural development.

Materials and Methods

This research was carried out in Florina Prefecture (Greece) and more specifically in the broader area of the Prespes municipality by means of questionnaires completed by producers during personal interviews. The sample studied in this research comprised all forty local producers that joined the PGI certification, according to the data of the Agricultural Cooperative “Pelekanos” and of the Union of Agricultural Cooperatives of Florina Prefecture and an equal number of non-certified bean producers. To make this research easier and more effective, two different questionnaires were created for each of the bean producer groups (certified and non-certified farmers) with the same or similar questions. The questionnaire was divided into three basic units: the first included questions on the personal features of the farm leaders, their networking as well as their training during their active years in agriculture; the second unit dealt with general features of the farms, and the third unit comprised attitudes, motives and sources of information that led bean producers to adopt the certification. Therefore, all factors that affected the producer decision to adopt or not to adopt this certification system were successfully recorded.

Primary data were analyzed using SPSS 17.0 Statistics, where descriptive statistics measures were used for the study of the leaders' personal data. The logit model was used for the indication of factors that affect the producers' decision to certify or not to certify their product as PGI and Stata 9 was used for the estimation of the logit model.

The choice of adopting new technologies or innovations (in our case the choice of certifying or not certifying a product as PGI) can be described by the following probability function (cumulative probability distribution function) which gives the adoption probability (Cramer, 2004; Gujarati, 2003; Greene, 2000):

Adoption probability = $$P(Y_i = 1) = 1/(1 + e^{-(\beta_0 + \beta_{1x1} + \dots \beta_{ixi}})) \qquad (1)$$

According to Equation (1), if P is the probability of adopting a new technology – innovation, then 1 – P is the probability of not adopting the technology – innovation as shown in the following Equation (2):

$$1 - P_i = 1/1 + e^{Z_i} \qquad (2)$$

Consequently, according to Equations (1) and (2), we could write the following:

$$P(Y_i = 1)/(1 - P(Y_i = 1)) = 1 + e^{Z_i} / 1 + e^{-Z_i} = e^{\beta_0 + \beta_{1\chi 1} + \dots \beta_{i\chi i}} \qquad (3)$$

where odds ratio $P(Y_i = 1)/(1 - P(Y_i = 1))$ is the adoption probability to the non-adoption probability, the ratio being modified in every modification of the X_i independent variables.

According to Cramer (2004) and Gujarati (2003), the logit modification of the adoption probability $P(Y_i = 1)$ can be denoted as (Cramer, 2004; Gujarati, 2003):

$$L_i = Log[P(Y_i = 1)/(1 - P(Y_i = 1))] = Z \qquad (4)$$

where $Log[P(Y_i = 1)/(1 - P(Y_i = 1))]$ is the logarithm of the odds ratio. In this way, the logarithm becomes a linear function of the X_i independent variables and our model changes from classic linear (as to the parameters) to regression model.

The model is estimated in terms of econometrics in order to get the β_i coefficients. Moreover, the Hosmer and Lemeshow $\hat{C}$ test was used for the goodness of fit estimation. The statistical $\hat{C}$ is considered to be distributed according to Pearson's χ^2 distribution. The χ^2 value corresponding to the significance level of $\alpha > 0.05$ proves that the logistic regression model fits the data well.

Finally, an additional measure for the goodness of fit test of the logit model is the correct classification of observations between the different groups (certified and non-certified Prespes beans producers). This measure includes the number of observations made correctly and erroneously based on the probability of an incidence (e.g. certification and non-certification). If the estimating probability is higher than 0.5, then the producer has adopted the certification; on the other hand, if the probability is lower than 0.5, the producer has not adopted the certification (Siardos, 2000).

The logit model for the case of "Local Traditional Product Certification as Protected Geographical Indication Products" is the following:

$$\text{Log}\ [P(y=1) / (1 - P(y = 1))] = \beta_o + \beta_1 SEX + \beta_2 AGE + \beta_3 TIME + \beta_4 INFORMATION + \beta_5 NETWORKING + \beta_6 TRADING + \beta_7 PRICES + \beta_8 QUALITY + \beta_9 SIZE \quad (5)$$

Four categories of variables were used for safer conclusions: a) variables describing personal characteristics of the producer (e.g., age, sex), b) variables expressing attitudes or motives of the producers (e.g., product trading, prices, quality assurance considered as entry motives), c) variables representing structural features of the cultivation (e.g., size of the cultivated land) and d) variables expressing possibility, means and strength of information (e.g., networking, information, etc.) (Oxouzi, 2008; Oxouzi and Papanagiotou, 2006; Pantzios et al., 2002; Neil et al., 1999).

The variables used in the logit model in order to define factors that affect the producers' decision to certify their local traditional products as PGI products are described in Table 1.

Table 1. Variables used in the logit model.

Dependent variable	Category	Description
Certification of local traditional products as PGI products	Binary	1 = YES 0 = NO
Independent variables		
AGE	Continuous	Age in years
SEX	Binary	1 = men 0 = women
TIME	Continuous	Years of agricultural experience
INFORMATION	Binary	1= frequent information by agriculturists 0 = rare information by agriculturists
NETWORKING	Binary	1111= a member of an agricultural cooperative or a producer group 0 0=non-member of an agricultural cooperative or a producer group
TRADING OF THE PRODUCT	Binary	1 = an important motive for the certification of products as PGI 0 = a non-important motive for the certification of products as PGI
PRICES	Binary	1 = an important motive for the certification of products as PGI 0 = a non-important motive for the certification of products as PGI
QUALITY	Binary	1 = an important motive for the certification of products as PGI 0 = a non-important motive for the certification of products as PGI
SIZE	Continuous	Cultivated land (hectares)

Results and Discussion

According to the research results (Table 2), the certified PGI producers were men in the majority (70.0%), farmers by profession (100.0%), 20–50 years old (average age: 43.4 years) and completed 9.5 years of education on average. Furthermore, 95.0% of the certified bean producers were members of an agricultural cooperative or a producer group, 60.0% attended agricultural seminars in the past and family tradition was the most important motive for becoming a farmer (47.5%).

The total size of the cultivated land of the PGI bean producers varied from 2.5 to 28 hectares, more specifically 10 hectares being the average size of the land. It is worth mentioning that the majority of the PGI bean producers (82.5%) had less than 25 years of agricultural experience, 17.5% of them had 25–35 years of experience and none of the certified producers worked in the agricultural sector for more than 35 years.

As to the personal features of the non-certified bean producers, most of them were men (77.5%), farmers by profession (92.5%); they were up to 50 years old (average age: 46.3 years) and completed 8.7 years of education on average. Here, we should underline the fact that 82.5% of the non-certified bean producers were not members of an agricultural union or a producer group and they never attended an agricultural seminar (82.5%), and they completed 8.7 years of education on average. The most important motive for the non-certified producers (55.0%) to become farmers by profession was family tradition.

The total size of the cultivated land of the non-certified bean producers varied from 1 to 14 hectares, more specifically 5 hectares being the average size of the area. As to the agricultural experience of the non-certified bean producers, the research has shown that 42.5% of them had up to 15 years of experience, 20.0% of them had 15–25 years of experience and 37.5% of them worked in the agricultural sector for more than 25 years (Table 2).

Consequently, the profile of the PGI certified and non-certified bean producers could be presented as in Table 2.

Table 2. The profile of the PGI certified and non-certified bean producers.

PGI producer	Non-certified PGI producer
Average age: 43.4 years old	Average age: 46.3 years old
Education: 9.5 years on average	Education: 8.7 years on average
Family tradition in agriculture	
Average size of bean cultivations: 10 hectares	Average size of bean cultivations: 5 hectares
Average agricultural experience: 19.32 years	Average agricultural experience: 20.10 years
Member of an agricultural cooperative or a producer group	Non-member of an agricultural cooperative or a producer group
He/she attended seminars on agriculture	He/she has not attended seminars on agriculture
Main profession: Farmer	

Source: Research data.

Tables 3 and 4 show separately the percentages, means and standard deviations of the independent variables incorporated in the logit model for PGI certified and non-certified bean producers.

Table 3. Descriptive statistics for continuous variables.

Variable	Non-certified as PGI (40)		Certified as PGI (40)	
	Mean	SD	Mean	SD
TIME (years)	20.10	10.04	19.32	7.21
SIZE (hectares)	4.97	3.23	9.99	5.63

SD, Standard deviation.

Table 4. Descriptive statistics for the nominal variables.

Variable	Non-certified as PGI (40)		Certified as PGI (40)	
	%	SD	**%**	SD
SEX (0,1)	0.77	0.42	0.70	0.46
INFORMATION (0,1)	0.17	0.38	0.60	0.49
NETWORKING (0,1)	0.32	0.47	0.95	0.22
TRADING OF THE PRODUCT (0,1)	0.62	0.49	0.87	0.33
PRICES (0,1)	0.85	0.36	0.95	0.22
QUALITY (0,1)	0.48	0.50	0.78	0.42

Estimation and results of the logit model

Table 5 shows that the following variables were statistically significant ($P<0.05$) in the integration of local traditional products in quality assurance schemes. These are producer farming experience, participation in a cooperative or a producer group, easier trading of the product, higher market prices, quality assurance of the product and total size of the cultivated land.

More specifically, the variables 'PRICES', 'TRADING OF THE PRODUCT' and 'QUALITY', that operate as motives for joining quality assurance schemes, were the most significant variables as concerned the probability of certifying the Prespes beans as a PGI product. Producers who considered higher market prices as an important motive for the product's certification as PGI were 45.3% more likely to join quality assurance schemes than those with different motives. In addition, the probability to adopt organic practices was 38.0% for producers who considered the easier trading of their products an important entry motive. Moreover, the research showed a positive correlation between the adoption probability of quality assurance schemes and product quality. Consequently, the Fassolia Prespon producers considering quality assurance of beans an important motive for their product certification as a protected geographical indication (PGI) product were more likely (29.73 times) to enter quality assurance schemes and to certify their product as PGI than those with different motives.

Another category of variables that affected the probability of adopting organic agriculture was the producer networking in cooperatives or other groups ('NETWORKING') and the years of agricultural experience ('TIME'). More specifically, the Fassolia Prespon producers that were members of a cooperative or other producer groups were 38.0% more likely to certify their product as PGI than the non-members of cooperatives or other groups.

On the contrary, the years of agricultural experience had a negative effect on the probability of adopting quality assurance schemes. The results showed that when time of agricultural experience increased by 1 unit (1 year), probability of joining quality assurance schemes decreased by 11.0%. Therefore, producers with longer agricultural experience were less likely to certify their product as a product of protected geographical indication compared to others.

Table 5. Results of the logit model concerning the probability of certifying Prespes beans as a PGI product.

	Odds ratio	Robust std. error	z	P > z
SEX	0.25	0.35	-0.97	0.330
AGE	0.92	0.06	-1.10	0.270
TIME	0.89	0.89	-2.24	0.025
INFORMATION	1.54	2.02	0.33	0.742
NETWORKING	38.01	36.16	3.07	0.002
TRADING	38.05	39.37	2.57	0.010
PRICES	45.28	13.97	2.73	0.006
QUALITY	29.73	45.89	2.20	0.028
SIZE	1.08	0.02	3.26	0.001
N	80	Wald chi^2 (9)	17.95	
Prob> chi^2	0.035	Pseudo R^2	0.716	

According to the results of this research, the total size of the cultivated land (‘SIZE’) had a positive effect on the probability of adopting quality assurance schemes. More specifically, when the size of the cultivated land increased by 1 unit (1 hectare), the probability of certifying the product as PGI increased 1.08 times. Consequently, Prespes bean producers that cultivated more hectares were, compared to others, more likely to enter quality assurance schemes.

The variables called ‘SEX’, ‘INFORMATION’ and ‘AGE’ were not statistically significant ($P<0.05$) to affect the producers’ decision to certify their product as PGI.

As mentioned before, a measure for the goodness of fit test of the logit model was the correct classification of observations between certified and non-certified bean producers (Table 6).

Table 6. Classification of observations.

Observed	Predicted		Correct prediction (%)
	Non-certified as PGI	Certified as PGI	
Non-certified as PGI	34	6	85.0
Certified as PGI	3	37	92.5
Total rate			88.8

According to Table 4, 85.0% of the producers that have not certified their product as PGI have been correctly predicted by the logit model that they have not joined quality assurance schemes. Similarly, 37 producers (92.5%) that certified their ‘Fassolia Prespon’ as a PGI product have been predicted correctly by the model. Only 9 producers were classified erroneously, and this result leads to the conclusion that the logit model was very well fitted to the data, as it predicted correctly 88.8% of the producers. The aforementioned conclusion is also verified by the Hosmer and Lemeshow test, where value $\chi^2 = 4.552$ corresponded to the level of significance $\alpha=0.804$, which means that the model was well fitted to the data.

Similarly to several other studies (Sparf, 2010; Teuber, 2011; Marchini et al., 2014; Danezis et al., 2016), the present study worked out that the higher price was the most important determinant in affecting the producer decision to certify his/her product as PGI in a positive way. The study revealed that one significant factor in determining the success of a geographical indication was that the certification added value to the product; specific characteristics or farming attributes of high quality food products distinguish them from similar offerings in the marketplace (Tregear et al., 2007; Hajdukiewicz, 2014; Belletti et al., 2017). According to Hajdukiewicz (2014), one factor with an important role in affecting the implementation was the producer membership in cooperative organizations. This result is also confirmed by the present study. Moreover, the present study findings indicate that product trading affected the adoption of the designation of origin. Many studies have shown that geographical indications play an increasingly important role in trade facilitation (Karipidis et al., 2009; Sparf, 2010; Hajdukiewicz, 2014). This study has identified more specific factors which affected the adoption. There was a strong link between the total size of the cultivated land and the positive probability of adoption. This study also revealed a statistically significant negative effect of the years of agricultural experience on the probability of adopting quality assurance schemes.

All the above results show that producer motives for adopting a new innovation were mostly economic. According to the results of the study, the type of the economic motive was the factor that had the most important role in affecting the producer decision to certify his/her product as PGI in a positive or negative way.

Therefore, taking measures that reinforce the market organization and create trading channels for the certified local traditional products may become more effective and may encourage more producers to adopt quality assurance schemes.

Conclusion

The purpose of this study is to indicate and analyze factors that affect the decisions of the Prespes bean ("Fassolia Prespon") producers to certify or not to certify their product as a product of protected geographical indication (PGI). Personal features of the producers, their attitudes and motives were also studied so that an accurate picture of the questions can be formed. Many factors can affect the adoption of quality assurance schemes by Prespes bean producers. Higher market prices, easier trading of the product, producers' participation in cooperatives or groups and quality assurance of the product had a positive effect on the probability of certifying the bean cultivation as PGI cultivation. Moreover, there was a positive correlation between the probability of adopting quality assurance schemes and the total size of cultivated land under beans. Producers of "Fassolia Prespon" with larger cultivated land were more likely to participate in quality assurance schemes compared to others. On the contrary, total length of agricultural experience had a negative effect on the probability of adopting quality assurance schemes and this means that producers with longer experience in agriculture, compared to others, were less likely to certify their product as PGI. It is worth mentioning that the most important determinants which were proved to be statistically significant belong to the category of certification motives (prices, trading and quality). This shows the great importance of these motives, not only for the adoption of quality assurance schemes by the producers, but for the continuation of implementation of these schemes as well. Therefore, the positive correlation between the aforementioned motives and the adoption of quality assurance schemes must encourage the introduction of measures that will not only provide a better price for the producer nor ascertain the trading of the product, but they will assure the quality of the local traditional product as well. In this way, the general development of the area will also be promoted. Measures that may serve the above purpose are the following:

a) the creation of cooperatives trading PGI products that will enhance the negotiating power of the producers and will, eventually, lead to better prices and easier trading of their products;

b) an advertising campaign that will inform the consumers at the national and international levels about the PGI products; this campaign will eventually enhance the negotiating power of the producers and achieve higher prices and easier trading of these products;

c) the creation of an agency specialized in the consumer information about products with protected geographical indication.

References

Belletti, G., Marescotti, A., & Touzard, J.M. (2017). Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies. *World Development, 98*, 45-57.

Borowska, A. (2010). The role of traditional and regional food products in rural development in Poland. *Social Research, 1* (18), 40-52.

Bouamra-Mechemache, Z., & Chaaban, J. (2010). Determinants of Adoption of Protected Designation of Origin Label: Evidence from the French Brie Cheese Industry. *Journal of Agricultural Economics*, *61* (2), 225-239.

Cramer, J.S. (2004). The early origins of the logit model. *Studies in History and Philosophy of Biological and Biomedical Science, 35*, 613-626.

Danezis, G.P., Tsagkaris, A.S., Brusic, V., & Georgiou, C.A. (2016). Food authentication: state of the art and prospects. *Current opinion in Food Science, 10*, 22-31.

European Commission. (2016). Agriculture and Rural Development. Door. Retrieved May 14, 2016, from http://ec.europa.eu/agriculture/quality/door/list.html?locale=en&recordStart=16&filter.dossierNumber=&filter.comboName=&filterMin.milestone__mask=&filterMin.milestone=&filterMax.milestone__mask=&filterMax.milestone=&filter.country=GR&filter.category=&filter.type=&filter.status=&recordPerPage=50.

Greene, W. (2000). *Econometric Analysis*. New Jersey: Prentice Hall Book Company.

Gujarati, D.N. (2003). *Basic Econometrics*. New York: Mc Graw- Hill Book Company.

Hajdukiewicz, A. (2014). European Union agri-food quality schemes for the protection and promotion of geographical indications and traditional specialties: An economic perspective. *Folia Horticulturae, 26* (1), 3-17.

Hellenic Statistical Authority (2016). Cultivation and production of agricultural crops. Retrieved May 14, 2016, from http://www.statistics.gr/portal/page/portal/ESYE/PAGE-database.

Karipidis, P., Athanassiadis, K., Aggelopoulos, S., & Giompliakis, E. (2009). Factors affecting the adoption of quality assurance systems in small food enterprises. *Food Control, 20,* 93-98.

Marchini, A., Riganelli, C., Diotallevi, F. & Paffarini, C. (2014). Factors of collective reputation of the Italian PDO wines: An analysis on central Italy. *Wine economics and policy, 3* (2), 127-137.

Neil, S.P., & Lee, D.R. (1999). Explaining the Adoption and Disadoption of Sustainable Agriculture: The Case of Cover Crops in Northern Honduras. *Economic Development and Cultural Change, 49* (4), 793-820.

Oxouzi, E. (2008). *Factors Determining the Adoption of Organic Viniculture in Central Macedonia (In Greek).* Doctoral thesis, School of Agriculture, Aristotle University of Thessaloniki.

Oxouzi, E., & Papanagiotou, E. (2006). Factors affecting the adoption of organic farming techniques in vine cultivation. *Proceedings of the 9th Panhellenic Conference of Agricultural Economy* (pp. 1019-1034). Athens, Greece.

Panagou, E., Nychas, G-Z., & Sofos, J. (2013). Types of traditional Greek foods and their safety. *Food Control, 29* (1), 32-41.

Pantzios, C., Tzinious, M., & Tzouvelekas, V. (2002). Factors Defining the Adoption of Organic Agriculture Techniques: The Case of Agricultural Exploitations in Crete (In Greek). *Proceedings of the 7th Panhellenic Conference of Agricultural Economy* (pp.110-124) Athens, Greece.

Parrott, N., Wilson, N., & Murdoch, J. (2002). Specialising quality-regional production and the alternative geography of food. *European Urban and Regional Studies, 9,* 241-261.

Scuderi, A., & Pecorino, B. (2015). Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) Italian citrus productions. *Acta Horticulturae,* 1022-2014.

Siardos, K.G. (2000). *Methods of multivariate statistical analysis* (In Greek). Thessaloniki: Ziti Book Company.

Sparf, B.M. (2010). *Protected Designation of Origin. Protected Geographical Indication -their significance for the growth of the food industries in France and Sweden.* Master thesis Department of Economics, Faculty of Natural Resources and Agricultural Sciences, Swedish University of Agricultural Sciences, Uppsala.

Teuber, R. (2011). Consumers' and producers' expectations towards geographical indications: Empirical evidence for a German case study. *British Food Journal, 113* (7), 900-918.

Tregear, A., Arfini, F., Belletti, G., & Marescotti, A. (2007). Regional foods and rural development: The role of product qualification. *Journal of Rural Studies, 23,* 12-22.

Trichopoulou, A., Soukara, S., & Vassilopoulou, E. (2007). Traditional foods: a science and society perspective. *Trends in Food Science & Technology, 18* (8), 420-427.

Received: October 31, 2018
Accepted: May 24, 2019

FAKTORI KOJI UTIČU NA INTEGRACIJU LOKALNIH TRADICIONALNIH PROIZVODA U SHEME KVALITETA POLJOPRIVREDNIH I PREHRAMBENIH PROIZVODA

Polyxeni Karagkiozi*, Eleni Oxouzi i Evangelos Papanagiotou

Odsek za agroekonomiju, Poljoprivredni fakultet,
Aristotelov univerzitet u Solunu, Grčka

R e z i m e

Ovim radom se istražuju faktori koji utiču na odluke proizvođača pasulja (Fassolia ’Prespon’) iz Prespe da sertifikuju svoj proizvod kao proizvod sa zaštićenom geografskom oznakom (engl. *protected geographical indication* – PGI). Istraživanje je zasnovano na primarnim podacima sakupljenim pomoću upitnika, koji su popunjavali kako sertifikovani proizvođači proizvoda sa zaštićenom geografskom oznakom tako i nesertifikovani proizvođači. Za ukazivanje na faktore koji utiču na odluke proizvođača da sertifikuju ili ne sertifikuju svoj proizvod, kao proizvod sa zaštićenom geografskom oznakom, korišćen je logit model. Deskriptivna statistika je korišćena za proučavanje socijalnih karakteristika lidera. Rezultati istraživanja su pokazali da je odluka proizvođača da se opredele za zaštitu geografskih oznaka značajno povezana sa članstvom u proizvođačkim organizacijama (zadrugama ili drugim grupama), godinama iskustva u bavljenju poljoprivredom, veličinom obrađenog zemljišta kao i motivima za usvajanje shema kvaliteta.

Ključne reči: logistički model, lokalni proizvodi, pasulj iz Prespe, zaštićena geografska oznaka, faktori.

Primljeno: 31. oktobra 2019.
Odobreno: 24. maja 2019.

*Autor za kontakt: e-mail: xeniakarag@gmail.com

Journal of Agricultural Sciences
Vol. 64, No. 2, 2019
Pages 203-214

https://doi.org/10.2298/JAS1902203S
UDC: 631.15(669)
Original scientific paper

THE EFFECT OF SUSTAINABLE LAND MANAGEMENT TECHNOLOGIES ON FARMING HOUSEHOLD FOOD SECURITY IN KWARA STATE, NIGERIA

Shehu A. Salau*, Robiu O. Aliu and Nofiu B. Nofiu

Department of Agricultural Economics and Extension Services,
College of Agriculture, Kwara State University, Malete, Nigeria

Abstract: Nigeria is among countries of the world confronted with the food insecurity problem. The agricultural production systems that produce food for the teeming population are not sustainable. Consequently, the use of Sustainable Land Management (SLM) technologies becomes a viable option. This study assessed the effect of SLM technologies on farming households' food security in Kwara State, Nigeria. A random sampling technique was used to pick 200 farming households for this study. The analytical tools included descriptive statistics, Shriar index, Likert scale, food security index and logistic regression analysis. The results indicated that the average age of the respondents was 51.8 years. The food security index showed that the proportions of food secure and insecure households were 35% and 65% respectively. The binary logistic regression revealed that SLM technologies were one of the critical determinants of food security. An increase in the usage of SLM technologies by 0.106% raised food security by 1%. Other important factors that were estimated included farm income, family size, gender and age of the household head. To reduce the effects of food insecurity, the effective coping strategies adopted by the respondents were reduction in quantity and quality of food consumed, engaging in off-farm jobs to increase household income and using of money proposed for other purposes to buy foods. Governments at all levels should encourage the adoption and use of SLM technologies through both print and electronic media. Policies and strategies towards reducing the household size should be vigorously pursued to reduce food insecurity.

Key words: agricultural practices, coping strategies, farming households, food security, SLM technologies and logistic regression.

*Corresponding author: e-mail: talk2salaushehu@yahoo.com

Introduction

Food is the key to life. It represents a large part of typical Nigerian household expenses. Thus, food security is critical to any country of the world. Food security occurs when all people, at all times, have physical, civic and financial means to provide adequate, safe and nourishing food that satisfies their dietary requirements and food choices for an energetic and beneficial life (FAO, 2005). Food insecure and secure households are those whose food intake falls below and above their minimum calorie requirements respectively.

In spite of the available resources and the efforts made by governments at different times, food insecurity remained one of the most significant challenges to Nigeria's economic development (Ifeoma and Agwu, 2014). The cost of food insecurity is substantially high. The poor performance of the agricultural sector deepens the food security problem of the country. Thus, it becomes more pertinent to increase the productivity of the sector. The agricultural sector is expected to create foods for the people. The agricultural production technologies and practices adopted to a greater extent determine whether a farmer will be food secure or not. Knowing the best technologies and practices to achieve this goal is significant (Branca et al., 2013). The disadvantages of the dominant model of agricultural intensification include the increased use of capital inputs and problems of economic feasibility (IAASTD, 2009). Consequently, concern is given to the alternative method of intensification such as the use of SLM technologies. SLM technologies refer to practices and technologies that relate to the management of land, water, biodiversity, and other resources to meet human needs without endangering the ecosystems. The adoption of SLM technologies can lead to improved soil texture and structure as well as it can raise the activity of soil flora and fauna (World Bank, 2006; Pretty, 2011). It can also make farmers less vulnerable to climatic risks. Many studies (Ahmed et al., 2016; Amaza et al., 2008; Omonona et al., 2007; Babatunde et al., 2007) have been carried out to investigate factors influencing food security of households. However, none of these studies have assessed the effect of SLM technologies on household food security. Thus, this study measured food security status, assessed the effect of SLM technologies on food security and described the reliable coping strategies used by the respondents to reduce the effect of food insecurity.

Materials and Methods

Area of study

The study area was Kwara state. The latitude and longitude of the state are: 8º and 10º north and 3º and 6º east respectively. The state has an area of 35,705 sq kilometers with a population of 193,392,500 people (NPC, 2016). To the west, Kwara state shares the international boundary with the Republic of Benin and to the north, the interstate boundaries with Niger state. It also shares boundaries with Oyo, Osun and Kogi states to the southwest, southeast and east respectively (Figure 1).

The climate consists of both wet and dry seasons each lasting for nearly six months. The raining season starts in April and ends in October while the dry season commences in November and stops in March. Temperatures range from 33°C to 34°C, with the total annual rainfall of about 1,318mm. The main occupation of the people is agriculture. The common crops grown are cassava, millet, maize, okra, sorghum, beniseed, cowpea, yam, sweet potatoes, and palm tree. The state has about 1,258 rural communities and the rural dwellers are the majority. Based on ecological characteristics, cultural practices and project administrative convenience, the state is categorized into four zones by Kwara state Agricultural Development Project (KWADP). These are: Zone A: Baruteen and Kaima Local Government Areas (LGAs); Zone B: Edu and Patigi LGAs; Zone C: Asa, Ilorin East, Ilorin South, Ilorin West and Moro LGAs and Zone D: Ekiti, Ifelodun, Irepodun, Offa, Oyun, Isin and Oke-Ero LGAs (KWADPs, 2010).

Figure 1. Map of Kwara state, Nigeria.
Source: Adapted from Ibiremo et al. (2010).

Results and Discussion

Method of data collection and sampling

Primary data were gathered using a structured interview schedule. A three-stage random sampling procedure was adopted for this study. Two out of the four

ADP zones were randomly selected in the first stage. This was followed by a proportionate selection of 20 villages from the two selected zones. Lastly, ten farming households each were picked randomly from the chosen villages to make a total of 200 farming households as shown in Table 1. The state has about 185,000 farm families (KWADPs, 2010).

Table 1. Village distribution in the zones.

Zones	Village distribution	Sampled villages	Sampled households
Zone B	237	7	70
Zone C	483	13	130
Total	720	20	200

Analytical framework

The tool of analysis comprised: descriptive statistics, Likert scale, food security index and logistic regression. The socio-economic features as well as the effective critical strategies adopted by respondents were explained using descriptive statistics. The respondents were further grouped into food secure and food insecure households using food security index. The index is stated as follows:

Fi = Per capita food expenditure for the i^{th} household divided by 2/3 mean per capita food expenditure (MPCFE) of all households;

where Fi = Food security index,

when Fi > 1 = Household is food secure, and

Fi < 1 = Household is food insecure.

A situation where the per capita monthly food expenditure (PCMFE) of a household is larger or equal to two-thirds of MPCFE the household is food secure. On the other hand, a food insecure household is a situation where the PCMFE is smaller than two-thirds of MPCFE (Omonona et al., 2007). The proportion of food secure/insecure households was estimated using the headcount ratio (H) as follows:

$$H = \frac{M}{N} \quad (1)$$

Headcount ratio $(H) = \frac{M}{N}$,

where M = Proportion of food secure/insecure households, N = Proportion of households in the sample.

To ascertain the effect of SLM technologies on household food security, a binary logistic regression model was employed.

The model is stated as:

$$Z = m_o + m_1X_1 + m_2X_2 + \ldots + m_kX_k + u, \quad (2)$$

where Z = Explained variable,

mo = Constant,
$m_1, m_2,\ldots,m_k$ = Coefficients,
X = Explanatory variables,
K = Number of explanatory factors,
P = Probability,
u = Error term.
The explanatory factors are:
X_1 = SLM technologies which were measured using Shriar index (2005),
X_2 = Estimated farm income (₦),
X_3 = Number of years of schooling (years),
X_4 = Household size (adult equivalent),
X_5 = Co-operative membership; (COOP) (Yes=1; No=0 for COOP),
X_6 = Sex of household head (D=1 for male; D=0 for female),
X_7 = Age of the respondents (years).

Estimation of Shriar index

Table 2 shows the different SLM technologies, the scale ranges and their associated weights.

Table 2. SLM technologies employed.

SLM technologies	Scale range	Weight	Max. points
Agronomy			
Cover crops	0–3	3.5	10.5
Intercropping	0–3	3.0	9
Organic fertilizer			
Compost	0–1	3.0	3
Animal and green manure	0–1	3.0	3
Min. soil disturbance			
Minimum tillage	0–3	2.5	7.5
Mulching	0–1	3.0	3
Water management			
Terraces	0–1	3.0	3
Water harvesting	0–1	3.0	3
Agroforestry			
Trees on crop land	0–1	2.0	2
Fallowing	0–1	2.0	2
Total			46

Adapted from Salau et al. (2011).

Table 2 shows that not all the farming activities could justify 0–3 scaling. From all the activities, the maximum attainable point was 46. The SLM index is given as:

$$SLM = \sum_{j=1}^{10} S_J W_J \qquad i=1 \ldots N \ldots\ldots (3)$$

where:

SLM = Sustainable Land Management technology index for the i^{th} household,
S = Scale range for the activities employed by the i^{th} household, and
W = Weight of the activities used by the i^{th} household.

If a household is engaged in any activity, it gets point 1 and 0 otherwise. The scale range of 0–3 suggests that if the household is engaged in the activity and if so, it does so at low (1 point), medium (2 points), or high (3 points) scale. This classification was based on the percentage of the total area cultivated on which the strategy was employed. Production practices like the use of legumes are more endurable and so attracted the highest weighting of 3.5 (Salau et al., 2011). Intercropping with other crops besides legumes takes the value of 0, for no, and 1 (low), 2 (medium) and 3 (high) levels of activity respectively. The scale range of organic fertilizer application, water management, agroforestry and mulching starts from 0 to 1 – zero for no activity, and 1 if used. The scale of minimum tillage takes the value of 0 for no activity, and 1, 2 and 3 for the use of tractor, animal traction and hoes/cutlass respectively.

To identify the effective coping strategies, a three-point Likert scale was employed. The response options and values assigned were as follows: very effective = 3; effective = 2; and not effective = 1. These values were added and divided by 3 to obtain the mean (2.0). Strategies with mean scores greater and lower than 2.0 will be regarded as effective and not effective respectively.

Socioeconomic characteristics of respondents

The majority (94.5%) of the respondents were males. Based on the culture and tradition of the people, the male respondents usually had more access to farmland when compared with the female respondents. The mean age of the respondents was 51.8 years. This implies that most of the respondents were aged. Age is a critical variable which can affect the ability and agility with which the head meets the food needs of the household. An old household head is more likely to have a larger family size and may lack the energy required to work for the upkeep and sustenance of the family (Table 3).

About 35% of the household heads had access to credit facilities from cooperative societies. Access to credit facilities may affect the type of food eaten and expenses of households. A large (62.5%) proportion of the household heads were literate. Hence, the respondents are supposed to be able to take good decisions which will likely enhance their food security status (Babatunde et al., 2007). The respondents operated at a subsistence level with a mean farm size of 1.5 hectares. The size of farmland cultivated may affect production and food security of the respondents (Akinsanmi and Doppler, 2005). Furthermore, the study revealed that most (62.5%) respondents received between ₦50, 000 and ₦100, 000 monthly from agricultural and non-agricultural related jobs respectively.

Table 3. Socioeconomic characteristics of the respondents.

Variable	Frequency	Percentage	Mean
Age			
1–30	27	13.5	
31–60	104	52.0	
61–90	69	34.5	51.8
Gender			
Male	189	94.5	
Female	11	5.5	
Level of education			
No formal education	75	37.5	
Primary	55	27.5	
Secondary	50	25.0	
Tertiary	18	9.0	
Postgraduate	2	1.0	
Marital status			
Single	25	12.5	
Married	174	87.0	
Divorced	1	0.5	
Household size			
1–5	71	35.5	
6–10	79	39.5	6.84
11–15	43	21.5	
16–20	7	3.5	
Primary source of income			
Agriculture	119	59.5	
Salary	61	30.5	
Trading	20	10.0	
Cooperative participation			
Yes	69	34.5	
No	131	65.5	
Estimated monthly income			
50,000–100,000	125	62.5	
101,000–150,000	49	24.5	
151,000–200,000	21	10.5	64,000
201,000–250,000	5	2.5	
Farm size (hectares)			
1–5	113	56.5	
6–10	68	34.0	1.59
11–15	11	5.5	
16–20	6	3.0	
21–25	2	1.0	

Source: Field survey, 2018.

Food security status of farming households

The calculated MPCFE was ₦4219.787. Households whose per capita food expenditure fell below and above ₦4219.787 were designated food insecure and food secure households respectively. Hence, 35% and 65% of the farming households were food secure and food insecure respectively (Table 4).

Table 4. Household food security status.

Variables	Mean		
	Food secure	Food insecure	All
2/3 mean per capita food expenditure was ₦4219.787			
Proportion of households	35.0	65.0	100
Number of households	70	130	200
Head count ratio (H)	0.35	0.65	

Source: Field survey, 2018.

Factors influencing food security of households

The result indicated an R^2 value of 48.1%. This suggests that about 50% of the total variation in the explained variable was accounted for by the explanatory variables. Factors influencing food security were the adoption of SLM technologies, estimated farm income, family size, gender and age of the household head (Table 5).

Table 5. Effects of SLM technologies on food security.

Food security	Coefficient	Std. Error	Sig.
SLM technologies	.106	.018	.000***
Estimated farm income	.000	.000	.003***
Level of education	-.001	.031	.982
Household size	-.310	.092	.001***
Cooperative participation	-.007	.466	.987
Gender	-.961	.523	.066*
Age	-.048	.023	.032**
Constant	-2.877	1.330	.030**

Source: Field survey, 2018; *, **, *** significant at the 1%, 5% and 10% levels respectively.

The coefficient of SLM technologies used was positive and critical at the 1% level. This suggests that the adoption of SLM technologies was an important factor influencing food security in the study area. An increase in the usage of SLM technologies by 0.106% raised food security by 1%. The higher the percentage of SLM technologies adopted, the larger the chance of being food secure. Estimated income is also significant at the 1% level. This implies that the higher the income of the households, the more secure the household is. These findings agree with those of Amaza et al. (2008) and Ifeoma and Agwu (2014). Household size was negative and it was also important at the 1% level of probability. This suggests that larger households may be food insecure. This finding agrees with those of Tilksew and Beyene (2012) and Ifeoma and Agwu (2014). Age of respondents was important at the 5% level, but it had a negative relationship with food security. This indicates that the young respondents were more food secure when compared with the aged ones. An old household head was more likely to have larger household size and may lack the energy required to work for the upkeep and sustenance of the households. Sex of the household head was also negative and important at the 5% level of probability. This suggests that female-headed households may be more food secure than their male counterparts. Surprisingly, education and cooperative participation were not the factors that influenced food security in the area.

Coping strategies employed by households

The most effective coping strategies adopted by respondents to reduce food insecurity included: reduction in quality of food eaten (M=2.06), consuming less preferred foods (M=2.09), using money budgeted for other uses to purchase foods (M= 2.14), doing off-farm jobs to raise income (M=2.12) (Table 6).

Table 6. Coping strategies adopted by the respondents.

Coping strategy	Mean	Std. deviation
Eating less preferred foods	2.09*	0.602
Lowering the quality of food intake	2.06*	0.696
Lowering the quantity of food intake	1.76	0.752
Borrowing food from friends and relatives	1.76	1.049
Borrowing money to purchase food	1.81	0.748
Mothers lowering their food intake for their children to eat enough	1.65	0.591
Avoiding one or two meals per day	1.60	0.666
Avoiding consuming food for one day	1.45	0.640
Engaging in prostitution and theft	1.51	0.626
Leaving children to cater for themselves	1.59	0.595
Lowering the number of people consuming food in the household	1.40	0.576
Consuming wild food	1.46	0.625
Income diversification	1.67	0.585
Asking for food on streets	1.58	0.613
Disposing assets	1.51	0.610
Distress migration	1.40	0.625
Consuming less expensive foods out of home	1.74	0.636
Doing off-farm jobs to raise income	2.12*	0.689
Purchasing meals on credit	1.72	0.778
Using funds budgeted for other uses to purchase food	2.14*	0.735
Depletion of stores	1.55	0.632

Source: Field survey, 2018; * effective coping strategies.

This finding agrees with the results of Haile et al. (2005), who have opined that engaging in off-farm and non-farm jobs is necessary for diversification of household income. Other strategies are borrowing food from friends and relatives (M=1.76), borrowing money to purchase food (M=1.81), purchasing food on credit (M=1.72), and lowering the number of people eating in the household (M=1.40). According to Ifeoma and Agwu (2014), household assets could be disposed to purchase food in times of adversity, crop failure and other eventualities.

Conclusion

This study assessed the influence of SLM technologies on household food security in Kwara state, Nigeria. The study indicated that 35% and 65% of the respondents were food secure and food insecure respectively, with an average age of 51.8 years. Furthermore, the adoption of SLM technologies was found to be significant in explaining food security of households in the state. An increase in the usage of SLM technologies by 0.106% increased food security by 1%. Other important determinants estimated were farm income, household size, gender and age of the household head. Moreover, reduction in quality of food consumed, engaging in off-farm jobs to raise income and diversion of funds budgeted for other uses to purchase foods were some of the effective coping strategies used by the respondents in reducing the effects of food insecurity. Consequently, it is recommended that the adoption and use of SLM technologies should be encouraged at local, state and federal levels by sensitizing farmers on the significance of SLM technologies through print and electronic media. Policies and strategies aimed at reducing household size should be formulated and implemented to reduce food insecurity.

References

Ahmed F.F., Eugene, C.E., & Abah, P.O. (2016). Analysis of food security among farming households in Borno State, Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences, 1* (1), 130-141.

Akinsanmi, A. & Doppler, W., (2005). Socio-economic and food security of farming families in Southeast Nigeria. Paper presented at Tropentary, 2005, Conference on international agricultural research and development. University of Honhentiem, Stuttgart, Germany.

Amaza, P.S., Adejobi, A.O., & Fregene, T., (2008). Measurement and determinants of food insecurity Northeast Nigeria: Some empirical policy guidelines. *Journal of Food, Agriculture and Environment, 6* (2), 92-96.

Babatunde, R.O. Omotesho, O., & Sholotan, O.S., (2007). Socio-economic characteristics and food security status of farming households in Kwara State, North-Central Nigeria. *Pakistan Journal of Nutrition, 6,* 49-58.

Branca G., McCarthy N., Lipper L., & Jolejole, M.C. (2013). Food security, climate change and sustainable land management. A review. *Agronomy for sustainable development, 33*, 635-650.

FAO, (2005). Food and agricultural organization. The state of food insecurity in the world, 2005, Rome, 2.

Haile, H.K., & Alemu, Z.G., (2005). Causes of household food insecurity in Koredegaga peasant association, Oromiya zone. Ethiopia working paper. Department of Agric Extension, Faculty of Natural and Agricultural Sciences at the University of Free State, Africa, 2-8.

IAASTD, (2009). Agriculture at the crossroads. Island Press, International Assessment of Agricultural Knowledge, Science and Technology for Development, Washington, DC.

Ibiremo, O.S., Ipinmoroti, R. R., Ogunlade, M.O., Daniel, M.A., & Iremiren, G.O. (2010). Assessment of Soil Fertility for Cocoa Production in Kwara State: Southern Guinea Savanna Zone of Nigeria. *Journal Agricultural Science, 1* (1), 11-18.

Ifeoma, J.I., & Agwu, E.A. (2014). Assessment of Food Security Situation among Farming Households in Rural Areas of Kano State, Nigeria. *Journal of Central European Agriculture, 15* (1), 94-107.

Kwara State Agricultural Development Projects (KWADPs) Progress Report 2000. From<Kwaraadp.com> (Retrieved on 4 June 2018).

Muhammed-Lawal Abdulazeez (2008). Analysis of food insecurity situation in rural households in Kwara State, Nigeria, unpublished Ph.D. Thesis, Department of Agricultural Economics and Farm Management, Faculty of Agriculture, University of Ilorin, Ilorin, Nigeria.

National Population Commission, (2016). *National population of Nigeria,* (2016).

Omonona, B., Agoi, T., & Adetokunbo, G. (2007). An analysis of food security situation among Nigerian urban households: Evidence from Lagos State, Nigeria. *Journal of Central of European Agriculture, 8* (3), 399-406.

Pretty, J.N. (2011). Editorial: sustainable intensification in Africa. International Journal of Agricultural Sustainability *9* (1), 3-4.

Salau, S.A., Adewumi, M.O., Omotesho, O.A., & Ayinde, O.E. (2011). A Comparative Analysis of Crop Production Intensification and its Determinants among Kwara and Niger States Maize Based Farming Households. *Journal of Agricultural Sciences, 3* (2), 97-105.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature, 418,* 671-677.

Tilksew, G.B., & Fekadu, B. (2013). Factors influencing Rural Household Food Insecurity: The case of Babile district East Hararghe zone, *Ethiopia Journal of Development and Agricultural Economics, 6* (4), 149-158.

World Bank (2006). *Sustainable land management: challenges, opportunities, and trade-offs*. The World Bank, Washington, DC.

Received: May 2, 2018
Accepted: February 28, 2019

UTICAJ TEHNOLOGIJA ZA ODRŽIVO UPRAVLJANJE ZEMLJIŠTEM NA PREHRAMBENU SIGURNOST POLJOPRIVREDNIH DOMAĆINSTAVA U DRŽAVI KVARA, NIGERIJA

Shehu A. Salau*, Robiu O. Aliu i Nofiu B. Nofiu

Odsek za agroekonomiju i savetodavne usluge, Poljoprivredni koledž, Državni univerzitet u Kvari, Malete, Nigerija

R e z i m e

Nigerija je među zemljama koje se suočavaju sa problemom prehrambene nesigurnosti. Sistemi poljoprivredne proizvodnje koji proizvode hranu za rastuću populaciju nisu održivi. Shodno tome, upotreba tehnologija za održivo upravljanje zemljištem (engl. *Sustainable Land Management* – SLM) postaje održiva opcija. Ovim istraživanjem se procenjuje uticaj tehnologija za održivo upravljanje zemljištem na prehrambenu sigurnost poljoprivrednih domaćinstava u državi Kvara u Nigeriji. Za ovo istraživanje korišćena je tehnika slučajnog uzorkovanja za odabir 200 poljoprivrednih domaćinstava. Analitički alati uključivali su deskriptivnu statistiku, Šriarov indeks, Likertovu skalu, indeks prehrambene sigurnosti i logističku regresionu analizu. Rezultati su pokazali da je prosečna starost ispitanika bila 51,8 godina. Indeks prehrambene sigurnosti pokazao je da su proporcije prehrambeno sigurnih i nesigurnih domaćinstava bile 35% odnosno 65%. Binarna logistička regresija pokazala je da SLM tehnologije predstavljaju jednu od važnih determinanti za prehrambenu sigurnost. Povećanje upotrebe ovih tehnologija za 0,106% povećalo je prehrambenu sigurnost za 1%. Ostali važni faktori koji su procenjivani uključivali su prihod domaćinstva, veličinu porodice, pol i starost nosioca domaćinstva. Da bi se smanjili uticaji prehrambene nesigurnosti, efikasne strategije suočavanja koje su ispitanici usvojili obuhvatale su smanjenje kvantiteta i kvaliteta hrane koja se konzumira, angažovanje na poslovima van gazdinstva kako bi se povećao prihod domaćinstva i korišćenje novca namenjenog za druge svrhe za kupovinu hrane. Vlade na svim nivoima bi trebalo da ohrabre usvajanje i upotrebu tehnologija za održivo upravljanje zemljištem kako putem štampanih tako i putem elektronskih medija. Politike i strategije u pravcu smanjenja veličine domaćinstva trebalo bi odlučno slediti kako bi se smanjila prehrambena nesigurnost.

Ključne reči: poljoprivredne prakse, strategije suočavanja, poljoprivredna domaćinstva, prehrambena sigurnost, SLM tehnologije i logistička regresija.

Primljeno: 2. maja 2018.
Odobreno: 28. februara 2019.

*Autor za kontakt: e-mail: talk2salaushehu@yahoo.com

INSTRUCTIONS FOR AUTHORS

MANUSCRIPT SUBMISSION

By submitting a manuscript authors warrant that their contribution to the Journal is their original work, that it has not been published before, that it is not under consideration for publication elsewhere, and that its publication has been approved by all co-authors, if any, and tacitly or explicitly by the responsible authorities at the institution where the work was carried out.
Authors are exclusively responsible for the contents of their submissions, the validity of the experimental results and must make sure that they have permission from all involved parties to make the data public.
Authors wishing to include figures or text passages that have already been published elsewhere are required to obtain permission from the copyright holder(s) and to include evidence that such permission has been granted when submitting their papers. Any material received without such evidence will be assumed to originate from the authors.
Authors must make sure that all only contributors who have significantly contributed to the submission are listed as authors and, conversely, that all contributors who have significantly contributed to the submission are listed as authors.
The registration of the authors and the submission of the papers should be done via the following link: http://aseestant.ceon.rs/index.php/jas/user
Manuscripts are to be pre-evaluated at the Editorial Office in order to check whether they meet the basic publishing requirements and quality standards. They are also screened for plagiarism.
Authors will be notified by email upon receiving their submission. Only those contributions which conform to the following instructions can be accepted for peer-review. Otherwise, the manuscripts shall be returned to the authors with observations, comments and annotations.

MANUSCRIPT PREPARATION

Authors must follow the instructions for authors strictly, failing which the manuscripts would be rejected without review.
The manuscript should be written in MS-Word in .doc, .docx, format. Font Times New Roman, font size 12, single spacing, margin 2.5 cm should be used when writing the paper. Page numbering should be avoided.
Original scientific paper - The paper should report the unpublished results of original research. This paper should occupy 6 to 12 pages.
Review article - The article which contains original, detailed and critical review of research problem or area where the author has made a certain contribution, noticed by auto citation (at least 10). This article should occupy 15 to 20 pages.
Preliminary communication - Original research paper of full format, small-scale or preliminary character. It should occupy 2 to 6 pages.

The obligatory parts of each Original scientific paper and Preliminary communication are the following: Title of the paper, Name(s) of author(s), Complete postal address(es) of affiliations, Abstract, Key words, Introduction, Material and Methods, Results and Discussion, Conclusion, Acknowledgements, References and Summary in Serbian (if manuscript is submitted in English and vice versa). The obligatory parts of each Review article are the following: Title of the paper, Name(s) of author(s), Complete postal address(es) of affiliations, Abstract, Key words, Introduction, Analysis-discussion of a certain topic, Conclusion, References and Summary in Serbian (if manuscript is submitted in English and vice versa). If manuscript is written in English British version is preferred.

Title of the paper

The title of the paper should describe the content of the paper as accurately and concisely as possible. Authors are recommended to use words in the title which are suitable for indexing and browsing purposes. The title should be centred and written in capital letters. If the paper has already been announced at certain meeting as an oral presentation, under the same or similar title, the datum should be stated on it at the bottom of the first page, after the data of the corresponding author.

Authors' Names

First name, middle initial(s) and last (family) name of all authors, in the original form, should be provided. The names should be written below the title, in lower-case letters, centred and bolded. If several different affiliations need to be mentioned, using the command "insert footnote", consecutive numerals should be placed as the superscript after the respective author's name. The corresponding author should be designated with an asterisk as the superscript, after the last (family) name, and his/her e-mail address should be given under the line, at the bottom of the first page of the paper.

Authors' Affiliations

The full name and address of the institution where the author is employed should be provided. It should be centred and written immediately after the author's name. If authors belong to different institutions, the numerals should be placed as the superscript before the name of institution to provide information on the institution where each of the stated authors is employed.

Abstract

The abstract is a short informative review of the content of the paper, which should enable the reader to estimate its relevance easily and accurately. It is in the interests of the author that the abstract contains terms used for indexing and browsing purposes. The references should not be given in the abstract. The abstract should include the aim of research, the methods, the results and the conclusion. It should contain between 200 and 250 words and be placed between the name of the authors' affiliations and key words. The title of the abstract should be bolded and indented pressing the tab key. The colon should be used after the title of the abstract, and then the text of the abstract should follow without any indentation.

Key words

Key words are terms or phrases which describe best the content of the article for the needs of indexing and browsing purposes. The number of key words should be 3 to 10. They should appear below the abstract. The title of key words should be bolded and indented by pressing the tab key. The colon should be used after the title, and then the list of key words in lower-case letters should be given with the full stop at the end. Key words should be provided in Serbian and English after abstract on both languages.

Introduction

The introduction should contain all the relevant information on past researches according to the stated problem and what can be achieved by further research. Reviewing the references, the author and the year should be provided, and the mentioned author should be cited in References. The title of the introduction should be centred and bolded, written in lower-case letters, below which using one line spacing, the text of the introduction should follow, justified. Each new paragraph should be indented pressing the tab key. These rules should be applied to all parts of the paper.

Material and Methods

The material and methods should be clearly outlined explaining all applied procedures in the paper. Generally known methods should be presented briefly, and a detailed explanation should be given if there is a deviation from previously published procedures. Papers, which have an experimental character, should provide the way of statistical data processing. This part, as well as the part Results and Discussion, if needed, may comprise certain subparts, too.

Results and Discussion

In the part Results and Discussion data obtained on the basis of observation and conducted experiments should be interpreted. In the comment of the results, references should be quoted at the end of the paper, providing the comparison between the obtained results and previous knowledge of the certain area.

Conclusion

All relevant items achieved in the researched area should be mentioned in the conclusion. Listing of all results with repetition of numbers previously specified in Results and Discussion should be avoided. Conclusion should not contain references.

Acknowledgements

Acknowledgements should contain the title and the number of the project that is the title of the program within which the paper was written, as well as the name of the institution which financed the project or program. It should be placed between the conclusion and references.

References
The References section should contain only papers cited in the main text. The paper cited in the text should contain the last (family) name and the year. If the citation is comprised of one author, it is stated as Jalikop (2010) or (Jalikop, 2010). When the citation is comprised of the two authors it is stated as Sadras and Soar (2009) or (Sadras and Soar, 2009). If more than two authors are cited, after the last (family) name of the first author, the abbreviation "et al." is given, and then the year. This citation is stated as Lehrer et al. (2008) or (Lehrer et al., 2008). If more than one paper are cited simultaneously for a certain problem, they should be listed chronologically. A large number of cited papers out of brackets should be separated by comma (,) and if in brackets, by semicolon (;). If two or more papers of the same author are cited, they must be listed chronologically (1997, 2002, 2006, etc.). If a certain author appears several times for the same year, the letters are added (2005a, b, c, etc.). The citations of personal communication and unpublished papers should be avoided, except that it is an absolute necessity. Such citations should appear in the text only as (Brown, personal communication), and not in the list of References.
The references, cited in the text should be stated in the list of references in the original form, alphabetically, without numbering. If a greater number of publications of the same author is cited, then the papers where the author is the single author should first be cited and then the publications of the same author with one and then with more co-authors. If a considerable number of publications appear in any of the above mentioned categories, they should be listed chronologically (1997, 2002, 2006, etc.), and if a great number of publications is of the same year then the letters are added (2005a, 2005b, 2005c, etc.). References entry should contain: the last (family) name of the author, the first letter of the author's name, the year of publishing in the brackets, the title of the paper, the title of the journal, the volume and the number of pages (the first-the last). When the book is cited, the publisher and place of publishing should be given. The lines of each reference entry should be indented after the first line. APA - Publication Manual of the American Psychological Association citation style is used in this journal.

The examples of listing references are the following:

Periodicals
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.

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

Book chapter
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.

Proceedings
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, France.

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

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

Web site
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

Summary
The summary in Serbian is given at the end of the paper and should comprise 200 to 250 words. Before the main text of the summary, as well as in English, the title of the paper, first name, middle initial(s) and last (family) name of all authors and the names and addresses of affiliations should be given. The title of the summary is centred and written separately. Below the title, the text of the summary should follow, without any indentation, and immediately after the text of the summary, the key words are given with the full stop at the end. The e-mail address of the corresponding author should be given at the bottom of the page.

Tables
Tables numbered with Arabic numerals (1, 2, etc.), followed by the title should be placed in the text using 9 font size and a maximum width of 13 cm. They should be clear, simple and unambiguous. The vertical sections should be avoided, and the number of columns should be limited so that the table is not too wide. Also, an unnecessary usage of horizontal sections should be avoided. The title of the table, single spaced above the table, justified, and with the full stop at the end should be given. The detailed explanation of abbreviations, symbols and signs used in the table should be provided below the table. Each table must be mentioned in the text.

Illustrations
All graphs, diagrams and photographs should be titled "Figure" (1, 2, etc.). They should be placed in the text. Graphs and diagrams should be computer drawn, using 9 font size and a maximum width of 13 cm, so that they can be legible and distinct after the size reduction. The overuse of colours and hues should be avoided for aesthetic reasons. The detailed legend without abbreviations for each graph and

diagram should be given. The photographs must be of high quality so that they can technically be well reproduced. They should be submitted in "TIF" or "JPG" format, and they will be printed in black and white. The title of the illustration should be justified, with a full stop at the end, single spaced from the illustration and given below it. Each illustration should be mentioned in the text.

Abbreviations and units

Only standardised abbreviations should be used in the paper. Measure units should be expressed using International System of Units (SI). The abbreviations can be used for other expressions provided these expressions are stated in the full form when appear for the first time with the abbreviated form in the brackets. Values from 1 to 9 can be written in letters, but others numerically.

Nomenclature

The complete nomenclature (chemical and biochemical, taxonomical, genetic etc.) must be adjusted to international codes and commissions, such as *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* etc.

Formulae

All formulae and equations in the paper should be worked out by means of the programme "WORD Equation". An ample space should be left around the formulae for the sake of visibility. Subscripts and superscripts should be clear. Greek letters and other non-Latin symbols should be explained when they are first used. The meaning of all symbols should be given immediately after the equation where these symbols are first used. Equations should be numbered by Arabic numerals, serially in brackets, at the right-hand side. Each equation must be mentioned in the text as Eq. (1), Eq. (2), etc.

The corresponding author will be sent a free copy of the journal after it has been published.

All future associates are asked to prepare the paper according to the given instructions in order to facilitate the work of the Editorial Board. Unless the paper is prepared according to the given instructions it will not be accepted for the prospective publishing.

Editorial Board of the Journal
Journal of Agricultural Sciences

UPUTSTVO AUTORIMA

SLANJE RUKOPISA

Prilikim podnošenja rukopisa autori garantuju da rukopis predstavlja njihov originalan doprinos, da nije već objavljen, da se ne razmatra za objavljivanje kod drugog izdavača ili u okviru neke druge publikacije, da je objavljivanje odobreno od strane svih koautora, ukoliko ih ima, kao i, prećutno ili eksplicitno, od strane nadležnih tela u ustanovi u kojoj je izvršeno istraživanje.
Autori snose svu odgovornost za sadržaj ponesenih rukopisa, kao i validnost eksperimentalnih rezultata, i moraju da pribave dozvolu za objavljivanje podataka od svih strana uključenih u istraživanje.
Autori koji žele da u rad uključe slike ili delove teksta koji su već negde objavljeni dužni su da za to pribave saglasnost nosilaca autorskih prava i da prilikom podnošenja rada dostave dokaze da je takva saglasnost data. Materijal za koji takvi dokazi nisu dostavljeni smatraće se originalnim delom autora.
Autori garantuju, da su kao autori navedena samo ona lica koja su značajno doprinela sadržaju rukopisa, odnosno da su sva lica koja su značajno doprinela sadržaju rukopisa navedena kao autori. Registracija autora i prijava radova se vrši preko linka: http://aseestant.ceon.rs/index.php/jas/user
Pri prijavi rada autori treba da navedu podatke za kontakt (ime i prezime, ustanovu i E-mail adresu) najmanje tri potencijalna recenzenta. Oni treba da budu eksperti iz date oblasti istraživanja koji će obezbediti objektivnu procenu rada. Predloženi recenzenti ne bi trebalo da budu iz iste institucije iz koje su i autori rada.
Nakon prijema, rukopisi prolaze kroz preliminarnu proveru u redakciji kako bi se proverilo da li ispunjavaju osnovne kriterijume i standarde. Pored toga, proverava se da li su rad ili njegovi delovi plagirani.
Autori će o prijemu rukopisa biti obavešteni elektronskom poštom. Samo oni rukopisi koji su u skladu sa datim uputstvima biće poslati na recenziju. U suprotnom, rukopis će, sa primedbama i komentarima, biti vraćen autorima.

UPUTSTVO ZA PRIPREMU RUKOPISA

Autori su dužni da se pridržavaju uputstva za pripremu radova. Rukopisi u kojima ova uputstva nisu poštovana biće odbijeni bez recenzije.

Za obradu teksta treba koristiti program MS-Word. Rukopise treba slati u jednom od sledećih formata .doc, .docx, koristiti font Times New Roman, veličina 12, jednostruki prored, margine 2,5 cm. Strane ne treba numerisati.
Originalan naučni rad – Rad koji sadrži prethodno neobjavljivane rezultate sopstvenih istraživanja. Obim ovog rada treba da iznosi od 6 do 12 strana.
Pregledni rad – Rad koji sadrži originalan, detaljan i kritički prikaz istraživačkog problema ili područja u kome je autor ostvario određeni doprinos, vidljiv na osnovu autocitata (najmanje 10). Obim ovog rada treba da iznosi od 15 do 20 strana.

Prethodno saopštenje – Originalan naučni rad punog formata, ali manjeg obima ili preliminarnog karaktera (od 2 do 6 strana).

Obavezna poglavlja svakog originalnog naučnog rada i prethodnog saopštenja su sledeća: naslov rada, imena autora, naziv ustanove autora, sažetak, ključne reči, uvod, materijal i metode, rezultati i diskusija, zaključak, zahvalnica, literatura i rezime na srpskom jeziku (ako je rad na engleskom i obrnuto). Pregledni rad mora da sadrži: naslov rada, imena autora, naziv ustanove autora, sažetak, ključne reči, uvod, analizu-diskusiju određene teme, zaključak, literaturu i rezime na srpskom jeziku (ako je rad na engleskom i obrnuto). Ako su radovi na engleskom jeziku, prednost se daje britanskoj varijanti ovog jezika.

Naslov rada

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.

Imena autora

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.

Naziv ustanove autora

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.

Redakcioni odbor časopisa
JOURNAL OF AGRICULTURAL SCIENCES

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

63

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