UDC: 63 ISSN 1450-8109

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE

Vol. 67, No. 3, 2022

Published by University of Belgrade
Faculty of Agriculture
Republic of Serbia

UDC: 63 ISSN 1450-8109

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE

Vol. 67, No. 3, 2022

Published by University of Belgrade
Faculty of Agriculture
Republic of Serbia

Journal of Agricultural Sciences (Belgrade) www.joas.agrif.bg.ac.rs
J. Agric. Sci (Bg).

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, Scopus, DOAJ

Number of institutions the Journal is exchanged with: 80

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE
Vol. 67, No. 3, 2022

C O N T E N T S

JOURNAL OF AGRICULTURAL SCIENCES BELGRADE
Vol. 67, No. 3, 2022

S A D R Ž A J

Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2203219A
Vol. 67, No. 3, 2022 UDC: 635.64:631.87(669)
Pages 219-235 Original scientific paper

THE INFLUENCE OF SIAM WEED COMPOST AND INORGANIC FERTILISER APPLICATIONS ON TOMATO PERFORMANCE

Tajudeen B. Akinrinola* **and Hassan Tijani-Eniola**

Department of Crop and Horticultural Sciences,
University of Ibadan, Ibadan, Nigeria

Abstract: Tomato is an important vegetable crop with high soil nutrient requirements. Hence, improvement in soil fertility status must be met through the use of readily available nutrient sources. *Chromolaena odorata* is widely spread in the country, and its compost has the potential of improving tomato yield. However, there is a dearth of information on the response of tomatoes to *Chromolaena* Compost (CC) and NPK fertiliser interactions. In the 4 x 3 factorial arrangement, CC at 0, 6, 8 and 10 t/ha and NPK 15-15-15 at 0, 15 and 30 kg N/ha were evaluated in a completely randomised design and a randomised complete block design for pot and field studies, using 10 kg/pot soil and 33333 plants/ha, respectively, with 3 replicates. Data on growth and yield parameters were subjected to analysis of variances by using SAS version 9.0. In the pot, the interaction of 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser gave a significantly higher number of leaves, number of branches, leaf area and the highest fruit set at 49 days after transplanting compared to other treatments. In the field, the number of fruits/plant (20.89) was significantly higher with the interaction of 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser, while 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser treatment gave the significantly higher fruit size (64.61 g) and yield (31.73 t/ha) compared to the control (11.33, 32.09 g and 9.66 t/ha, respectively). The application of 8 t/ha of CC with 30 kg N/ha of NPK 15-15-15 fertiliser was therefore recommended.

Key words: *Chromolaena* compost, NPK 15-15-15, fertiliser interactions, growth, fruit yield.

Introduction

Tomato (*Solanum lycopersicum* L.) is important in terms of diet and economy in Nigeria. It is a crop with high nutritional requirements, and its production is influenced by the availability of nutrients (Upendra et al., 2000), among other factors. Apart from varietal variations, tomato fruit quality and quantity are greatly

*Corresponding author: e-mail: tb.akinrinola@gmail.com

influenced by the nutrient levels and fertility of the soil. Tisdale et al. (2003) and Adeboye et al. (2009) have reported that a very high level of soil fertility is required for the successful production of tomatoes. These nutrient requirements are met with different nutrient sources, which vary depending on the cultural practices adopted by the farmer.

Tomatoes grow moderately over a wide range of soil types. However, besides nutrient levels, certain soil criteria must also be satisfied in terms of the soil structure and soil organic matter content to optimise its production. Soil factors like nutrient composition, soil pH, effective soil depth, compaction and water holding capacity have been reported to significantly influence the resulting yield (Nweke and Nsoanya, 2013).

Nigerian soils are reported to be mainly Alfisols and Ultisols, which are inherently of low-activity clays characterised by low nutrient content, low pH, low organic matter content and high susceptibility to erosion (Agboola and Omueti, 1982; Asadu et al., 2004; Ayeni, 2011). In order to achieve high yields of good quality, it is, therefore, essential to apply fertilisers to such soils (Upendra et al., 2000; Oyinlola and Jinadu, 2012). The use of organic or conventional sources of nutrients has influenced soils, yields and compositions of fruits in different ways. The effects of sole organic fertilisers or NPK 15-15-15 fertilisers, or when combined, on the growth and yield of tomatoes have been documented (Ayoola and Adeniyan, 2006; Nnabude et al., 2014; AL-Kahtani et al., 2018). Similarly, their respective detrimental effects on soil qualities and bulkiness have also been documented (Agboola and Omueti, 1982; Rosen and Allan, 2007). However, reports have shown the advantages of the combined application of inorganic and organic fertilisers over their single application on the quality and yield of tomatoes (Kisetu and Heri, 2014; Ogundare et al., 2015; Islam et al., 2017) and okra (Fasakin et al., 2019). Siam weed is an invasive weed that spreads extensively in large areas of farmland in Southwest Nigeria (Uyi et al., 2014). The application of the Siam weed extract to increase *Celosia argentea* yield has been reported (Ilori et al., 2011). Similarly, the application of the Siam weed compost to improve tomato fruit yield has been documented (Akinrinola, 2018). However, there are few studies on how varying levels of Siam weed compost and NPK 15-15-15 affect the yield of tomatoes. Therefore, this study was carried out to determine the optimum level of the Siam weed compost and NPK 15-15-15 fertiliser application best for the growth and yield of tomatoes.

Material and Methods

A pot experiment was conducted before the rains on an open field beside the screenhouse of the Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Oyo State, Nigeria. In addition, the field experiment was conducted

in 2017 at the Research Farm of the Department of Agronomy, Ibadan, Oyo State. The soil sample collected for the pot study was obtained from the Department of Agronomy Research Farm and was air-dried, crushed and sieved with a 2–mm sieve. Some of the sieved samples were used to determine the physical and chemical properties of the soil, while the remaining soil was used for the screenhouse study.

Soil analysis: Soil pH in water was determined using a glass electrode pH meter in 1:1 soil/water suspensions, while organic carbon was determined by the wet oxidation method of Walkley and Black (1934). Total N was determined using the Kjeldahl method, and Bray 1-P was used for available P extraction. Exchangeable bases (Ca, Mg, K and Na) were extracted using l M ammonium acetate solution at pH 7. Calcium and magnesium concentrations were determined with an atomic absorption spectrophotometer. Potassium and sodium were determined with a flame emission photometer. Micronutrients (Cu, Zn, Mn and Fe) were extracted using l M HCl solution, and the micronutrients in the solution were read using the atomic absorption spectrophotometer, according to Juo (1979). The hydrometer method, as described by Bouyoucos (1951), was used to determine the soil particle size distribution.

The results of the physical and chemical analysis are presented in Table 1. The texture of the soil used in the study was loamy sand soil, dominated by a sand fraction (868 g/kg). The soil pH value was 6.8 in H_2O. Values observed for organic carbon (2.85 g/kg), available phosphorus (3.04 g/kg) and exchangeable cations (Ca, Mg, Na, and K) are shown in Table 1. The exchangeable acidity and micronutrients are shown in Table 1. Concentrations of nutrient elements in the *Chromolaena odorata* compost used in this experiment are presented in Table 2.

The treatments consisted of four levels of the *Chromolaena odorata* compost (at 0, 6, 8 and 10 t/ha) and three levels of NPK 15-15-15 fertiliser (at 0, 15, and 30 kg N/ha) in a factorial arrangement. The experimental designs used were a completely randomised design for the pot study, and a randomised complete block design for the field study. Each experiment was replicated three times. Seeds of the tomato cultivar 'Ibadan local' used in the trials were obtained from the National Horticultural Research Institute, Ibadan, Oyo State, Nigeria.

Prior to pot and field experiments, the tomato seedlings were raised for four weeks in the nursery. Sieved soil (10 kg) was weighed into each pot of the polyethylene bag that had been perforated for free drainage in the pot experiment. In the field, tomato seedlings raised on nursery trays were transplanted into experimental plots, each measuring 1.2 m x 4.8 m, previously ploughed and harrowed. Tomato seedlings (Ibadan local cultivar) were transplanted at four weeks after planting at the rate of two seedlings per pot or per stand in the field at 60 cm x 50 cm spacing (33333 plants/ha). The seedlings were thinned down to one seedling per pot or per stand at 2 weeks after transplanting.

Table 1. The pre-planting physical and chemical properties of the soil used.

Properties	Values
Physical properties	
Gravel	27.2
Sand	868
Silt	60
Clay	72
Textural classification	Loamy sand
Chemical properties	
pH (1:1 H_2O)	6.8
Organic carbon (g/kg)	2.85
C/N ratio	12.81
Available P (g/kg)	3.04
Base saturation	98.6
Exchangeable acidity (g/kg)	0.08
Ca	5.17
Mg	1.15
K	0.38
Na	0.38
Exchangeable micronutrient (g/kg)	
Mn	125.6
Fe	15.1
Cu	3.2
Zn	13.5

Table 2. The concentration of nutrient elements in the *Chromolaena odorata* compost used in the study.

Elements	Concentration (% dry weight)
Organic matter	20.26
N	0.55
C/N ratio	21.31
P	0.13
K	1.60
Ca	0.49
Mg	0.29

The *Chromolaena odorata* compost was applied at 2 weeks before transplanting. The NPK 15-15-15 fertiliser was applied at 2 weeks after transplanting. Each pot was irrigated with water every other day to field capacity during the course of the experiment, while weeding was done manually at 4, 8, and 12 weeks after transplanting. Plants were sprayed fortnightly with Mancozeb 63% + carbendazim 12.5% @ 25 kg/ha for the control of fungi diseases using a knapsack sprayer.

Data collection: At 49 Days After Transplanting (DAT), data measured in the pot and field experiments included plant height, number of branches/plant, leaf

area/plant using the formula of Carmassi et al. (2007) formula and days to 50% flowering. Also, the fruit set was recorded at 49 DAT for the pot experiment, while yield parameters such as the number of fruits/plant, fruit size and fresh fruit yield (t/ha) were measured for the field experiment. The data obtained in the field experiment were taken from three plants randomly selected within the middle row in a plot, tagged and used to determine the growth parameters and the yield (fruit number and weight) per plant. Harvesting of mature fruits was done twice weekly at the orange to the red stage from 49 DAT to 79 DAT. All the data determined were as reported by Akinrinola (2018).

Statistical analysis: To test for differences among treatments, data collected were subjected to analysis of variance (ANOVA) and the means that were significantly different were separated using LSD at a 0.05% level of probability.

Results and Discussion

Soil properties

The analysis of soil physical properties (Table 1) showed that the soil was very high in sand and low in silt and clay contents. This soil is likely to support tomato production, as reported by Oyinlola and Jinadu (2012). In addition, the soil chemical properties used in this study indicated low levels of nutrients as recommended for sustainable tomato production (Sainju et al., 2003). These implied that the soil water retention would be adequate, while the nutrient supply ability of soil to support tomato production would be poor. Hence, such soil will likely respond to a good level of organic matter improvement. The concentration of mineral elements in the *Chromolaena odorata* compost material used in this experiment (Table 2) was similar to that earlier reported by Akinrinola (2018). The ability of Siam weed compost to support the nutrient need for tomatoes has been reported by Akinrinola (2018), likewise its extract to support *Celosia argentea* production by Ilori et al. (2011).

Effects of the *Chromolaena odorata* compost on the growth and yield of tomatoes

In the pot experiment, the application of CC did not significantly increase tomato height (Table 3). There was a significant influence of different levels of CC application on the number of leaves of tomatoes. The highest number of leaves per plant was observed with the application of CC at 8 t/ha. On the other hand, the lowest number of leaves was observed in the control, but the value was not significantly different from the number of leaves observed at 6 t/ha of CC. The observed numbers of branches at 8 and 10 t/ha were significantly higher compared

to those at 0 and 6 t/ha of CC, which did not differ significantly. Applying CC significantly increased leaf area in tomatoes. The highest leaf area was observed at 8 t/ha, while the lowest was observed in the control. The highest value was not significantly different from the leaf area obtained from the plants treated with 10 t/ha. Also, the lowest leaf area did not differ significantly from that obtained at 6 t/ha. The number of days to 50% flowering was not significantly improved by CC (Table 3). The fruit set was significantly improved with the application of 8 and 10 t/ha of CC compared to 6 t/ha, which was also significantly higher than the control.

Table 3. The influence of *Chromolaena odorata* compost on the growth and yield parameters of tomatoes under pot conditions.

Treatments (t/ha)	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	Fruit set
0	51.30	17.05	1.77	346.53	41.25	1.22
6	62.97	22.38	2.00	450.89	37.17	1.99
8	64.86	42.78	4.66	748.13	32.92	3.22
10	67.07	33.55	4.22	600.32	33.33	3.78
LSD	ns	8.54	1.00	154.82	ns	0.76

ns = Not significant at the 0.05 probability level.

Table 4. The influence of *Chromolaena odorata* compost on the growth and yield parameters of tomatoes under field conditions.

Treatments (t/ha)	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	No. of fruits/plant	Size/ fruit	Fruit yield (t/ha)
0	63.97	31.25	5.50	1459.49	35.65	10.57	41.98	14.18
6	80.04	40.94	6.32	2528.24	32.53	15.16	43.58	21.60
8	87.75	48.54	8.10	3363.78	32.87	13.76	47.18	21.62
10	93.32	59.97	7.81	4054.85	30.78	18.93	49.56	27.07
LSD	18.83	10.18	1.48	596.56	ns	3.46	ns	4.09

ns = Not significant at the 0.05 probability level.

In the field, the application of 8 and 10 t/ha of CC significantly increased tomato plant height compared to the control at 49 DAT (Table 4). The number of leaves in tomatoes was significantly improved by the application of 10 t/ha compared to 6 t/ha and the control. Also, the application of 8 t/ha of CC differed significantly from the control, but not from 6 or 10 t/ha of CC within treatments. *Chromolaema odorata* compost significantly improved the number of branches in tomatoes. The highest number of branches was observed under the application of 8 t/ha of CC, while the lowest was observed in the control. An increase in the CC application significantly increased leaf area with each successive increase in the level of application. Hence, the highest leaf area was observed at 10 t/ha, while the

least in the control. The application of CC did not have a significant influence on days to 50% flowering in tomatoes. The number of fruits/plant was significantly enhanced by the application of CC (Table 4). The plants treated with 10 t/ha of CC had a significantly higher number of fruits compared to the other treatments. Similarly, 8 t/ha of CC significantly increased the number of fruits compared to the control. The application of CC had no significant influence on tomato fruit size. The use of CC improved the fruit yield in tomatoes. The application of 10 t/ha of CC significantly increased tomato fruit yield compared to the other treatments. Applications of 6 and 8 t/ha of CC did not differ significantly, but they were significantly higher than the control.

The observed pot and field data indicated that the application of the *Chromolaena odorata* compost, NPK 15-15-15 fertiliser or their interactions significantly affected most variables monitored in tomato plants. The observed responses of tomato variables to the application of the *Chromolaena odorata* compost were consistent with the responses observed by Akinrinola (2018) on the growth and yield variables of tomatoes. Similarly, the impact of crop waste as an organic-based fertiliser in improving crop performances was reported by several researchers (Fawole et al., 2016; Fasakin et al., 2019; Priyadarshani and Thayamini, 2020). The improvement in growth and yield can be attributed to the addition of soil organic matter, which is important for increasing soil nutrient supply, reducing soil loss, improving soil structure and water use efficiency, thereby maintaining soil health (Rosen and Allan, 2007; Bitew and Alemayehu, 2017; Koopmans and Bloem, 2018). The increase in tomato performance may also be associated with an increase in microbial activity by the compost that enhances nutrient availability for uptake (Rosen and Allan, 2007).

Effects of NPK fertiliser on the growth and yield of tomatoes

In the pot experiment, the application of NPK 15-15-15 did not significantly increase tomato height (Table 5). A significantly higher number of leaves was observed at 30 kg N/ha of NPK 15-15-15 fertiliser compared to the other treatments. Each successive increase in NPK 15-15-15 fertiliser application resulted in a significant increase in tomato number of branches, with the highest and lowest observed at 30 kg N/ha and the control, respectively. The application of NPK 15-15-15 fertiliser significantly improved tomato leaf area, 30 kg N/ha was significantly higher compared to other levels of application. The number of days to 50% flowering was not significantly improved by NPK fertiliser application. Also, applying 15 and 30 kg N/ha of NPK 15-15-15 significantly enhanced the fruit set in tomatoes compared to the control.

Table 5. The performance of tomatoes as influenced by NPK 15-15-15 fertiliser under pot conditions.

Treatments (kg N/ha)	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	Fruit set
0	56.80	21.82	1.74	382.87	37.76	1.90
15	59.83	27.75	3.42	498.50	35.17	2.58
30	68.03	37.25	4.33	728.04	35.58	3.17
LSD	ns	7.39	0.86	134.08	ns	0.65

ns = Not significant at the 0.05 probability level.

Table 6. The performance of tomatoes as influenced by NPK 15-15-15 fertiliser under field conditions.

Treatments (kg N/ha)	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	No. of fruits/plant	Size/fruit	Fruit yield (t/ha)
0	75.21	38.21	6.08	2327.36	33.62	14.26	36.87	17.84
15	81.74	47.78	6.86	3260.36	32.58	13.33	46.45	19.83
30	86.86	49.53	7.86	2967.05	32.67	16.23	53.41	25.69
LSD	16.30	8.82	1.28	516.64	ns	ns	8.04	3.55

ns = Not significant at the 0.05 probability level.

Under field condition, applying NPK 15-15-15 significantly enhanced plant height and it increased with the increase in the level of application (Table 6). Also, the application of 8 t/ha of CC differed significantly from the control, but not from 6 or 10 t/ha of CC within treatments. Applying NPK 15-15-15 fertiliser at 15 and 30 kg N/ha enhanced the number of leaves in tomatoes significantly compared to the control. Applying NPK 15-15-15 fertiliser significantly improved branching in tomatoes at 30 kg N/ha compared to the control. The effects of 15 and 30 kg N/ha of NPK 15-15-15 fertiliser within treatments on tomato leaf area did not differ significantly, but differed significantly from the control. Also, NPK 15-15-15 fertiliser had no significant effect on days to 50% flowering. Treatments involving NPK 15-15-15 did not increase the number of fruits significantly (Table 6). However, the lowest and highest numbers of fruits were observed in plants treated with 15 and 30 kg N/ha, respectively. Treatments involving NPK 15-15-15 significantly enhanced fruit sizes, with a significant increase at 15 and 30 kg N/ha compared to the control. Increasing the NPK 15-15-15 fertiliser application improved tomato fruit yield, with the significance observed between 30 kg N/ha and the other treatments. However, no significant difference was observed between 15 kg N/ha and the control.

The improvements in tomato height, number of branches, number of leaves, leaf area, number of fruits and fruit yield and yield components are attributed to the

application of NPK fertiliser compared to the control, with the better influences observed at 30 kg N/ha. These were in support of earlier reports that the NPK fertiliser application improves growth and yield in tomatoes (Oyinlola and Jinadu, 2012; Ayoola and Adebayo, 2017; Akinrinola, 2018) and okra (Fasakin et al., 2019). The attributes of inorganic NPK fertilisers in crop improvement were associated with the supply of essential plant nutrients in forms that are soluble and easily assimilated by the plants for development. Hence, the application of inorganic fertiliser results in better crop performance, particularly in soil with a low fertility status (Tisdale et al., 2003).

The influence of *Chromolaena odorata* compost x NPK interactions on the growth and yield of tomatoes

In the pot experiment, the interaction of CC and NPK fertiliser had no significant influence on tomato height at 49 DAT (Table 7). The interaction of CC and NPK 15-15-15 fertiliser showed a significant influence on the number of leaves of tomatoes at 49 DAT. The highest and lowest values were observed at 8 t/ha of CC and 30 kg N/ha, and the control, respectively.

Table 7. The growth performance of tomatoes as influenced by the interactions of the *Chromolaena odorata* compost and NPK 15-15-15 fertiliser at 49 days after transplanting under pot conditions.

	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	Fruit set
0 t/ha + 0 kg	44.48	14.16	1.64	286.15	44.09	0.32
0 t/ha + 15 kg N/ha	50.43	17.00	1.67	337.11	41.00	1.00
0 t/ha + 30 kg N/ha	59.00	20.00	2.00	416.34	38.67	2.33
6 t/ha + 0 kg	60.89	16.46	0.99	319.13	36.86	1.63
6 t/ha + 15 kg N/ha	55.70	19.00	2.00	375.20	37.33	2.00
6 t/ha + 30 kg N/ha	72.33	31.67	3.00	658.34	37.33	2.33
8 t/ha + 0 kg	58.82	30.33	1.65	492.25	35.10	2.65
8 t/ha + 15 kg N/ha	65.77	45.67	6.00	739.00	31.67	4.33
8 t/ha + 30 kg N/ha	70.00	52.33	6.33	1013.13	32.00	4.00
10 t/ha + 0 kg	63.00	26.33	2.67	433.94	35.00	3.00
10 t/ha + 15 kg N/ha	67.40	29.33	4.00	542.68	30.67	3.00
10 t/ha + 30 kg N/ha	70.80	45.00	6.00	824.33	34.33	4.00
LSD	ns	14.79	1.73	268.16	ns	1.31

ns = Not significant at the 0.05 probability level.

The interaction of CC and NPK 15-15-15 showed a significant effect on the number of branches in tomatoes. The application of 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser gave the highest number of branches, but this did not differ

significantly from the values observed by applying 8 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser, and 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser. The lowest number of branches was observed at 6 t/ha of CC and 0 kg N/ha of NPK 15-15-15 fertiliser (Table 7). *Chromolaena odorata* compost and NPK fertiliser interactions significantly improved tomato leaf area at varying levels. The application of 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser gave the highest leaf area but did not differ significantly from the leaf area observed at 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser, and 8 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser. The lowest leaf area was observed in the control (Table 7). The number of days to 50% flowering was not significantly improved by CC and NPK fertiliser interactions. The interaction of CC and NPK 15-15-15 fertiliser increased tomato fruit set significantly at different levels of interactions. The interaction of 8 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser gave the highest tomato fruit set compared to the other treatments (Table 7).

In the field, the interaction of CC and NPK 15-15-15 fertiliser significantly increased tomato height at 8 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser, 10 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser, and 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser compared to the control (Table 8). The interaction of 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser significantly improved the number of leaves in tomatoes compared to the other treatments, except for treatments involving 15 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser and 10 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser (Table 8). Furthermore, there were significant interactions between CC and NPK fertiliser on tomato branching. Applying 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser gave the highest number of branches, while the least was observed in the control (Table 8). Interactions of CC and NPK 15-15-15 fertiliser on leaf area indicated a significant higher leaf area when 8 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser, and 10 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser were applied compared to the other treatment combinations, except 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser (Table 8). Similarly, the interaction of CC and NPK 15-15-15 showed no significant reduction in the number of days to 50% flowering. However, the least was observed in the treatment involving 10 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser, and the highest in the control (Table 8). The number of fruits/plant was significantly enhanced by the application of CC (Table 8). The interaction of CC and NPK 15-15-15 fertiliser resulted in a significant increase in the number of fruits in tomatoes. The interaction of 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser within the treatment gave the highest number of fruits, while the lowest was observed in plants treated with 0 t/ha of CC and 15 kg N/ha of NPK 15-15-15 fertiliser (Table 5). The interaction of CC and NPK 15-15-15 fertiliser significantly improved fruit

size in tomatoes at varying levels. The highest fruit size was observed in plants treated with 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser (Table 8). The interactions of CC and NPK 15-15-15 fertiliser varied significantly among treatments with respect to fruit yield. The highest fruit yield was observed in plants treated with 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 fertiliser. However, the fruit yield was not significantly different from the values observed in the interaction involving 10 t/ha of CC and 6 t/ha of CC with 30 kg N/ha of NPK 15-15-15 fertiliser. The least fruit yield was observed in the control (Table 8).

Table 8. The growth performance of tomatoes as influenced by the interactions of the *Chromolaena odorata* compost and NPK 15-15-15 fertiliser at 49 days after transplanting under field conditions.

	Plant height (cm)	No. of leaves/plant	No. of branches	Leaf area (cm^2)	50% flowering	No. of fruits/plant	Size/ fruit	Fruit yield (t/ha)
Siam weed compost x NPK 15-15-15 fertiliser								
0 t/ha + 0 kg	51.59	27.74	4.29	1222.71	37.28	10.92	31.45	9.47
0 t/ha + 15 kg N/ha	70.46	30.56	6.11	1201.84	33.00	10.22	45.71	14.67
0 t/ha + 30 kg N/ha	69.86	35.45	6.11	1953.93	36.67	10.56	48.77	18.40
6 t/ha + 0 kg	76.91	41.37	6.52	2725.18	32.59	14.38	42.22	20.47
6 t/ha + 15 kg N/ha	82.20	41.56	5.67	2255.08	34.00	12.44	46.52	20.27
6 t/ha + 30 kg N/ha	81.00	39.89	6.78	2604.47	31.00	18.67	41.99	24.05
8 t/ha + 0 kg	87.23	41.62	7.29	2417.64	32.62	13.95	31.81	15.64
8 t/ha + 15 kg N/ha	83.10	56.67	7.56	4533.73	34.00	12.55	45.12	17.50
8 t/ha + 30 kg N/ha	92.93	47.34	9.44	3139.96	32.00	14.78	64.61	31.73
10 t/ha + 0 kg	85.11	42.11	6.22	2943.91	32.00	17.78	41.98	25.77
10 t/ha + 15 kg N/ha	91.20	62.34	8.11	5050.79	29.33	18.11	48.43	26.86
10 t/ha + 30 kg N/ha	103.66	75.45	9.11	4169.84	31.00	20.89	58.26	28.58
LSD	32.61	17.64	2.56	1033.30	ns	6.00	16.08	7.10

ns = Not significant at the 0.05 probability level.

The basic principle reported to underlie the integrated nutrient management concept is the maintenance or improvement of soil fertility for sustainable crop production. This was evident in the better performances of tomatoes treated with the combined application of Siam weed compost and NPK 15-15-15 fertiliser compared to their sole applications. The improvement in the performance of tomatoes under integrated nutrient management practices has also been well documented (Kisetu and Heri, 2014; Ogundare et al., 2015; Islam et al., 2017). The combined application of inorganic and organic fertilisers has been reported to have a beneficial effect on mitigating the deficiency of micronutrients (Bitew and Alemayehu, 2017). Similarly, increased soil organic matter and available water holding capacity, and a decrease in soil bulk density have been reported to create a good soil condition for enhanced growth of crops (Agboola and Omueti, 1982;

Rosen and Allan, 2007). The results revealed that responses obtained from the combined application of CC and inorganic fertiliser were no exception to the benefits derived from integrated nutrient management. Subsequently, the better growth and yield of tomato crops when 8 t/ha of CC and 30 kg N/ha of NPK 15-15-15 were combined indicated that this level was better for the Ibadan local tomato cultivar. At a higher level of fertiliser application (i.e. 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15), the yield of tomatoes decreased. In addition, the chemical properties of the soil used in this study indicated that the soil was low in nutrients required for an optimum yield of tomatoes as recommended by Sainju et al. (2003). This may be explained by the fact that high tomato fruit yield and improved fruit quality are produced from optimum N fertiliser application (Oyinlola and Jinadu, 2012), while the abundant development of vegetative parts of the plant resulted from the excessive application at the expense of reproductive growth (Sainju et al., 2003; Tisdale et al., 2003).

Correlations between tomato growth and yield parameters

The Pearson correlation coefficient showed that plant height was significantly correlated to the number of leaves and days to 50% flowering (Table 9). Also, a high significant correlation ($p < 0.01$) was observed between the number of leaves and the number of branches, leaf area and fruit set at 49 DAT. Similarly, the number of branches and fruit set at 49 DAT were highly correlated. The observed leaf area was significantly correlated to fruit set at 49 DAT. The Pearson correlation coefficient indicated that the number of leaves and the number of branches were negatively correlated with days to 50% flowering, with a significant correlation observed with leaf area and fruit set at 49 DAT.

Table 9. The Pearson correlation coefficient of the growth and yield parameters considered in the pot experiment.

	Number of leaves	Number of branches	Leaf area	Days to 50% flowering	Fruit set
Plant height	0.36*	0.24	0.24	0.44**	0.25
Number of leaves		0.89**	0.79**	-0.13	0.46**
Number of branches			0.82**	-0.27	0.55**
Leaf area				-0.47**	0.44**
Days to 50% flowering					-0.38*

*; ** = The correlation is significant at the 0.05 and 0.01 levels, respectively.

Plant height was significantly correlated to the number of leaves and the number of fruits/plant, and had high significant ($p < 0.01$) correlations with the number of branches/plant, fruit size and fruit yield (Table 10). Similarly, a high

significant correlation was observed between the number of leaves, the number of branches and yield components. Leaf area was observed to correlate significantly with yield components and the yield of tomatoes. The number of fruits and fruit size correlated significantly with tomato fruit yield. All parameters correlated negatively with days to 50% flowering, and the significance was observed for plant height and leaf area.

Table 10. The Pearson correlation coefficient of the growth and yield parameters considered in the field experiment.

	Number of leaves	Number of branches	Leaf area	Days to 50% flowering	Number of fruits	Fruit sizes	Fruit yield
Plant height	0.40*	0.60**	0.51**	-0.64**	0.36*	0.51**	0.65**
Number of leaves		0.50**	0.82**	0.08	0.58**	0.34*	0.48**
Number of branches			0.61**	-0.16	0.34*	0.78**	0.58**
Leaf area				-0.38*	0.45**	0.38*	0.44**
Days to 50% flowering					0.03	-0.19	-0.28
Number of fruits						0.14	0.66**
Fruit sizes							0.59**

*; ** = The correlation is significant at the 0.05 and 0.01 levels, respectively.

The correlations between plant height, the number of leaves and leaf area are substantiated by Jo and Shin (2020). In addition, Sanam et al. (2022) report that the correlation in growth parameters varies in tomatoes. The negative relationship between days to 50% flowering and other growth parameters in the pot and field studies implied that an increase in vegetative growth was at the expense of flowering, especially in the leaf area. This was further affirmed by the negative correlation coefficient observed between days to 50% flowering and yield. According to Sainju et al. (2003), the insufficient nutrient status increased days to 50% flowering, while excess also delayed flowering. Similar findings have been reported on pigeon pea (Padi, 2003) and maize (Anjorin and Ogunniyan, 2014). The high correlation coefficient between leaf area and yield and the yield components of tomato indicated that the plant was able to translocate photosynthate to the fruit, thereby increasing the harvest. This finding supported the report of Hidaka et al. (2019) on strawberries. The leaf acts as a source from which photosynthates are translocated to the harvestable target organs. The same was also evident from the investigation of Liu et al. (2020), stating that the final grain yields in maize had a relationship with total leaf areas.

Conclusion

The result of this investigation further confirms a higher influence of the application of organic and mineral fertilisers over the single application of each fertiliser type on tomato growth and yield through soil fertility improvement. The application of Siam weed compost at 8 t/ha and 30 kg N/ha of NPK 15-15-15 increased tomato growth and yield over the other treatments. It was closely followed by 10 t/ha of CC and 30 kg N/ha of NPK 15-15-15 application. However, the influence of 8 t/ha of Siam weed compost and 30 kg N/ha of NPK 15-15-15 was concluded to be more effective and efficient for maximum tomato production.

References

Adeboye, M., Osunde, A., Ezenwa, M., Odofin, A., & Bala, A. (2009). Evaluation of the fertility status and suitability of some soils for arable cropping in the Southern Guinea Savanna of Nigeria. *Nigerian Journal of Soil Science*, *19* (2), 115-120.

Agboola, A.A., & Omueti, J.A. (1982). Soil fertility problem and its management in tropical Africa. In R. Lal, P.A. Sanchez, R.W. Cummings, Jr. (Eds.), *Proceedings of the International Conference on land clearing and development in the Tropics*, International Institute of Tropical Agriculture, (pp. 234-240). Ibadan, Nigeria.

Anjorin, F.B., & Ogunniyan, D.J. (2014). Comparison of growth and yield components of five quality protein maize varieties. Inter*national Journal of Agriculture and Forestry*, *4* (1), 1-5.

Akinrinola, T.B. (2018). Influence of Siam weed [Chromolaena odorata (L) King and Robinson] compost on the growth and yield of tomato (Solanum lycopersicon L.). *Nigerian Journal of Horticultural Science*, *23*, 46-53.

AL-Kahtani, S.H., Ahmed, M.A., Al-Selwey, W.A., & Abdel-Razzak, H.S. (2018). Evaluation of composted agricultural crop wastes application on growth, mineral content, yield, and fruit quality of tomato. *Journal of Experimental Biology and Agricultural Sciences*, *6* (1), 159-167.

Asadu, C.L.A., Ezeaku, P.I., & Nnaji, G.U. (2004). Land Use and Soil Management Situations in Nigeria: An Analytical Review of Changes. *Outlook on Agriculture*, *33* (1), 27-37.

Ayeni, L.S. (2011). Integrated plant nutrition management: A panacea for sustainable crop production in Nigeria. *International Journal of Soil Science*, *6*, 19-24.

Ayoola, O.T., & Adebayo, A.K. (2017). Response of local tomato varieties to application of poultry manure, cow dung and inorganic fertiliser. *Journal of Biology, Agriculture and Healthcare*, *7* (10), 31-38.

Ayoola, O.T., & Adeniyan, O.N. (2006). Influence of poultry manure and NPK fertiliser on yield and yield components of crops under different cropping systems in southwest Nigeria. *African Journal of Biotechnology*, *5,* 1386-1392.

Bitew, Y., & Alemayehu, M. (2017). Impact of crop production inputs on soil health- A review. *Asian Journal of Plant Science*, *16*, 109-131.

Bouyoucos, G.H. (1951). A recalibration of the hydrometer for making mechanical analysis of soils. *Journal of Agronomy, 43*, 434-438.

Carmassi, G., Incrocci, L., Incrocci, G., & Pardossi, A. (2007). Non-destructive estimation of leaf area in (Solanum lycopersicum L.) and gerbera (Gerbera jamesonii H. Bolus). *Agricoltura Mediterranea, 137*, 172-176.

Fasakin, K., Afe, A.I., & Saka, N.A. (2019). Growth and yield response of okra (Abelmoschus esculentus (L.) Moench) to fertilizer types and times of application in the southern guinea savanna agro-ecozone of Nigeria. *Journal of Agricultural Sciences, 64* (4), 353-366.

Fawole, O.B., Alor,iE. T., & Ojo, O.A. (2016). Evaluation of two composts for the improvement of crop yield using tomato (Lycopersicon esculentum) as test crop. *Journal of Agricultural Sciences, 61* (1), 37-44.

Hidaka, K., Miyoshi, Y., Ishii, S., Suzui, N., Yin, Y-G., Kurita, K., Nagao, K., Araki, T., Yasutake, D., Kitano, M., & Kawachi, N. (2019). Dynamic Analysis of Photosynthate Translocation Into Strawberry Fruits Using Non-invasive ^{11}C-Labeling Supported With Conventional Destructive Measurements Using ^{13}C-Labeling. *Frontier Plant Science 9,*1946.

Ilori, O.J., Ilori, O.O., Sanni, R.O., & Adenegan-Alakinde, T.A. (2011). Effect of Chromolaena odorata on the growth and biomass accumulation of Celosia argentea. *Research Journal of Environmental Sciences*, *5* (2), 200-204.

Islam, M.A., Islam, 1.S., Akter, A., Rahman, M.H., & Nandwani, D. (2017). Effect of organic and inorganic fertilisers on soil properties and the growth, yield and quality of tomato in Mymensingh, Bangladesh. *Agriculture*, *7*, 18-25.

Jo, W.J., & Shin, J.H. (2020). Effect of leaf-area management on tomato plant growth in greenhouses. *Horticulture, Environment, and Biotechnology, 61,* 981-988.

Juo, A.S.R. (1979). *Selected methods for soil and plant analysis*: Manual series No. 1. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Kisetu, E., & Heri, P. (2014). Effects of poultry manure and NPK (23:10:5) fertilizer on tomato variety tanya grown on selected soil of Morogoro Region, Tanzania. *Asian Journal of Crop Science*, *6* (2)*,* 165-175.

Koopmans, C.J., & Bloem, J. (2018). Soil quality effects of compost and manure in arable cropping. Results from using soil improvers for 17 years in the MAC trial. Louis Bolk Institute. Publication number 2018-001 LbP. 40pp. Retrieved May 05, 2019, from www.louisbolk.nl/publicaties

Liu, W., Ming, B., Xie, R., Liu, G., Wang, K., Yang, Y., Guo, X., Hou, P., & Li, S. (2020). Change in Maize Final Leaf Numbers and Its Effects on Biomass and Grain Yield across China. *Agriculture*, *10* (9), 411.

Nnabude, P.C., Nweke, I.A., & Nsoanya, L.N. (2014). Response of three varieties of tomatoes (Lycopersicon esculentum) to liquid organic fertiliser (alfa life) and inorganic fertiliser (NPK 20:10:10) and for soil improvements. *European Journal of Pure and Applied Chemistry*, *1,* 32-41.

Nweke, I.A., & Nsoanya, L.N. (2013). Soil pH: An indices for effective management of soils for crop production. *International Journal of Scientific and Technology Research*, *2,* 132-134.

Ogundare, S.K., Babalola, T.S., Hinmikaiye, A.S., & Oloniruha, J.A. (2015). Growth and fruit yield of tomato as influenced by combined use of organic and inorganic fertilizer in Kabba, Nigeria. *European Journal of Agriculture and Forestry Research*, *3,* 48-56.

Oyinlola, E.Y., & Jinadu, S.A. (2012). Growth, yield and nutrient concentrations of tomato as affected by soil textures and nitrogen. *Asian Journal of Agricultural Research*, *6,* 39-45.

Padi, F. K. (2003). Correlation and Path Coefficient Analyses of Yield and Yield Components in Pigeonpea. *Pakistan Journal of Biological Sciences, 6*, 1689-1694.

Priyadarshani, W.M.N., & Thayamini, H.S. (2020). The effects of goat manure and sugarcane molasses on the growth and yield of beetroot (Beta vulgaris L). *Journal of Agricultural Sciences (Belgrade), 65* (4), 321-335.

Rosen, C.J., & Allan, D.L. (2007). Exploring the benefits of organic nutrient sources for crop production and soil quality. *Hortechnology*, *17,* 422-430.

Sainju, U.M., Dris, R., & Singh, B. (2003). Mineral nutrition of tomato. *Journal of Food, Agriculture and Environment*, *1,* 176-183.

Sanam, T., Triveni, S., Sridhar, G.N., Ningoji, S.N., & Desai, S. (2022). Correlation and regression models of tomato yield in response to plant growth by different bacterial inoculants and inoculation methods. *Agronomy Journal, 114* (1), 452-460.

Tisdale, S.L., Nelson, W.L., Beaton, J.D., & Havlin, J.L. (2003). *Soil fertility and fertilisers*. 5th Edn., Prentice-Hall of India, Pvt Ltd., New Delhi, India.

Upendra, M.S., Ramdane, D., & Bharat, S. (2000). Mineral nutrition in tomato. *Food, Agriculture and Environment, 1*, 176-183.

Uyi, O.O., Ekhator, F., Ikuenobe, C.E., Borokini, T.I., Aigbokhan, E.I., Egbon, I.N., Adebayo, A.R., Igbinosa, I.B., Okeke, C.O., Igbinosa, E.O., & Omokhua, G.A. (2014). Chromolaena odorata invasion in Nigeria: A case for coordinated biological control. *Management of Biological Invasions*, *5,* 377-393.

Walkley, A., & Black, I.A. (1934). An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, *37,* 29-37.

Received: July 23, 2019
Accepted: July 4, 2022

UTICAJ PRIMENA KOMPOSTA OD SIJAMSKOG KOROVA I MINERALNIH ĐUBRIVA NA PRODUKTIVNOST PARADAJZA

Tajudeen B. Akinrinola* **i Hassan Tijani-Eniola**

Odsek za ratarstvo i hortikulturu,
Univerzitet u Ibadanu, Ibadan, Nigerija

R e z i m e

Paradajz je važna povrtarska kultura sa visokim zahtevima za hranljivim materijama u zemljištu. Stoga se poboljšanje plodnosti zemljišta može postići korišćenjem lako dostupnih izvora hranljivih materija. *Chromolaena odorata* (sijamski korov) je široko rasprostranjen korov u Nigeriji, a kompost koji se pravi od ove biljke ima potencijal da poveća prinos paradajza. Međutim, postoji nedostatak informacija o odgovoru paradajza na interakcije komposta koji se pravi od biljke *Chromolaena odorata* i NPK đubriva. U faktorijalnom rasporedu 4 x 3, pri dozi 0, 6, 8 i 10 t/ha komposta od sijamskog korova i pri dozi 0, 15 i 30 kg N/ha NPK 15-15-15 đubriva procenjeni su u potpuno slučajnom blok dizajnu za ispitivanje u sudovima i u polju, korišćenjem 10 kg/sudu odnosno 33333 biljaka/ha, sa 3 ponavljanja. Podaci o parametrima rasta i prinosa su obrađeni analizom varijansi korišćenjem programa SAS verzije 9.0. U sudovima je interakcija varijante sa 8 t/ha komposta od sijamskog korova i 30 kg N/ha NPK 15-15-15 đubriva dala značajno veći broj listova, broj grana, lisnu površinu i najviše plodova 49 dana nakon presađivanja u odnosu na druge tretmane. U polju je broj plodova/biljci (20,89) bio značajno veći uz interakciju varijante od 10 t/ha komposta od sijamskog korova i 30 kg N/ha NPK 15-15-15 đubriva, dok je tretman sa 8 t/ha komposta od sijamskog korova i 30 kg N/ha NPK 15-15-15 đubriva dao značajno veću masu ploda (64,61 g) i prinos (31,73 t/ha) u odnosu na kontrolu (11,33, 32,09 g odnosno 9,66 t/ha). Stoga je preporučena primena 8 t/ha komposta od sijamskog korova sa 30 kg N/ha NPK 15-15-15 đubriva.

Ključne reči: kompost od biljke *Chromolaena odorata*, NPK 15-15-15, interakcije đubriva, rast, prinos ploda.

Primljeno: 23. juli 2019.
Odobreno: 4. juli 2022.

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

Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2203237M
Vol. 67, No. 3, 2022 UDC: 633.522:577.175.1(477)
Pages 237-251 Original scientific paper

THE INFLUENCE OF EXOGENOUS GROWTH REGULATORS ON THE CANNABINOID CONTENT AND THE MAIN SELECTION TRAITS OF HEMP (*CANNABIS SATIVA* L. SSP. *SATIVA*)

Serhii V. Mishchenko[1], Iryna M. Laiko[1], Serhiy M. Tkachenko[1], Yurii O. Lavrynenko[2], Tetiana Y. Marchenko[2] and Olena O. Piliarska[2*]

[1]Institute of Bast Crops of the National Academy of Agrarian Sciences of Ukraine, 45 Tereshchenkiv Str., Hlukhiv, Sumy region, 41400, Ukraine
[2]Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, Naddniprianske, Kherson, 73483, Ukraine

Abstract: Hemp (*Cannabis sativa* L.) is a species sensitive to the influence of exogenous growth regulators, both in the treatment of vegetative plant tissues and *in vitro* culture. 1-naphthylacetic acid, indole-3-acetic acid, 2,4-dichlorophenoxyacetic acid, kinetin, 6-benzylaminopurine (BAP), gibberellic acid (GA_3), ascorbic acid and nicotinic acid of exogenous origin in the studied concentrations and doses caused a change in the content of cannabinoids in plants of the variety USO 31. Ascorbic acid, auxins and GA_3 significantly reduced the content of cannabinoids, whereas nicotinic acid and cytokinins increased it. Under the influence of nicotinic acid and BAP, a higher content of cannabinoid compounds was stably manifested during each of the three years of processing and it is inherited by at least one generation of descendants. An additional method to increase the level of non-psychotropic cannabinoids may be the treatment of vegetative plant tissues with cytokinin BAP (the concentration of 40 mg/l, the consumption rate of 30 ml/m^2, the phase of growth and development BBCH 51), which, in contrast to high concentrations of nicotinic acid, significantly increased the content of cannabidiol, and, to a lesser extent, tetrahydrocannabinol. The selection traits of the hemp – stem total length, mass and fiber content, seed productivity and sex determination significantly increased under treatment. A wide range of possibilities for phytohormones of exogenous origin in regulating cannabinoid accumulation, morphogenesis of hemp plants and their productivity was confirmed. Different hemp genotypes may have different responses to plant growth regulators and concentrations, which should be established in each case.

Key words: hemp, phytohormones, vitamins, cannabinoids, productivity, sex determination.

[*]Corresponding author: e-mail: izz.biblio@ukr.net

Introduction

Phytohormones are physiologically active substances that are synthesized in certain tissues and at different stages of plant development, occupying a central place in the regulation of growth, especially the differentiation of plants in general, as well as in the culture of isolated cells and tissues. Based on physiological functions, phytohormones are divided into five groups: 1) auxins; 2) gibberellins; 3) cytokinins; 4) gaseous compounds (such as ethylene); 5) compounds that induce growth retardation and aging (e.g., abscisic acid). According to the latest data, growth regulators also include jasmonic acid, brassinosteroids and salicylic acid (Neumann et al., 2020). Some phytohormones have been discovered relatively recently, but auxins, for example, have been known for more than a hundred years, playing a role in endocytosis regulation, cell polarity, cell cycle, embryogenesis, histogenesis and organogenesis, but their other broad physiological functions and mechanisms still remain unclear (Sauer et al., 2013; Sudan et al., 2014). Of considerable scientific interest is the study of the effectiveness of phytohormones of exogenous origin as regulators of growth and development on hemp plants (*Cannabis sativa* L.) – a worldwide multi-purpose culture. The researchers' attention is focused on the possibility of increasing the yield of stems, fibers and seeds of hemp in the open ground and on the development of new cultivation systems specific to different genotypes of medical use in the conditions of closed ground (Burgel et al., 2020; Mendel et al., 2020).

Within the known studies, hemp had a significant response to the exogenous use of 1-naphthylacetic acid (NAA) at the concentration of 5 mg/l, 10 mg/l and 20 mg/l and 6-benzylaminopurine (BAP) at the concentration of 10 mg/l, 25 mg/l and 50 mg/l, influencing apical dominance, branching of shoots, bast fiber formation and flavonoid content. Hemp is characterized by a standard response to cytokinin treatment comparable to that observed in peas and beans (Mendel et al., 2020). A synthetic analogue of NAA, auxin, increased the yield of bast fibers, and the reaction to it differed from the standard response. This finding requires further study to establish the possible synergistic effect of this phytohormone with other growth regulators, namely cytokinins and gibberellins, which can be achieved, for example, by studying phytohormones in the vascular structures of the stem by immunological methods (Mendel et al., 2020).

In other studies, the height of hemp plants decreased significantly due to the use of NAA (28%), BAP (18%) and a mixture of NAA and BAP (15%). The length of internodes also decreased by 58% (when using NAA) and by 30% (when using a mixture of NAA and BAP), and the number of internodes decreased by 15% (NAA), 10% (BAP) and by 14% (when using a mixture of NAA and BAP), compared to control without treatment (Burgel et al., 2020). NAA changed the habit of inflorescence, which became more compact, although the seed yield and content of cannabinoid compounds remained similar to the control variant.

Increasing the biomass of inflorescences in closed soil led to an increased gathering of cannabinoids per unit area (Burgel et al., 2020). In general, one important detail should be noted: the nature of the response to phytohormones is specific to each genotype (variety) (Burgel et al., 2020).

In hemp, apical dominance prevents the development of lateral shoots (branching of the inflorescence). It can be suppressed in two ways: the removal of apical meristems (Ačko et al., 2019) and the use of phytohormones that affect the height and lateral branching of plants, leading to increased seed yield, as proved in other crops, such as *Solanum tuberosum* L. (Kumlay, 2014), *Moringa oleifera* Lam. (Brockman et al., 2020). It is indole-3-acetic acid (IAA), which is synthesized at the top of the shoot in young leaves and transported basipetally to the roots, that plays a key role in maintaining apical dominance (Brockman et al., 2020), which is important to consider when developing a model for the optimal use of exogenous growth regulators for hemp.

An important issue in the cultivation of crops is to increase the resistance of plants to drought, which is becoming a complex environmental problem due to anthropogenic activities. The mechanism of response to drought includes morphophysiological, biochemical, cellular and molecular processes in the plants, including changes in the root system, leaf structure, osmotic regulation of water content, stomatal activity, etc. (Ilyas et al., 2021). Abscisic acid is considered to be the main hormone that enhances the drought resistance of plants. Jasmonic acid and salicylic acid, ethylene, auxins, gibberellins and cytokinins, as a result of interaction with each other (the synergism of action), play a vital role in regulating various phenomena in plants to adapt to drought (Ilyas et al., 2021; Ullah et al., 2018). The intensification of research into the mechanisms of hemp resistance to drought with the use of phytohormones of exogenous origin may also become one of the priority areas in crop production.

As for other crops, phytohormones are extremely important in the cultivation of hemp *in vitro* (Galán-Ávila et al., 2020; Chaohua et al., 2016; Lata et al., 2016), which is used for the genetic transformation of plants, microclonal propagation, obtaining new starting breeding material (by chemical mutagenesis or polyploidy), storage of germplasm, and so on. Obtaining cannabinoids (specific chemical compounds of cannabis used in the pharmaceutical industry and medical practice) from calluses and cell suspension cultures was impossible. The lateral roots may form a small amount of these metabolites, but their synthesis is completed over time, and as a result, cannabinoids are negligible for industrial applications (Wróbel et al., 2018). It will be advisable to develop (improve) a highly efficient protocol for direct *in vitro* regeneration of hemp plants from different explants. The main problems are the induction of callusogenesis and strong apical dominance, which are overcome through the use of auxin antagonist α-(2-oxo-2-phenylethyl)-1*H*-indole-3-acetic acid and synthetic cytokinin derivative 6-benzylamino-9-

(tetrahydroxypyranyl) purin (Smýkalová et al., 2019). It was determined that the most effective ratios of "auxin: cytokinin" in the nutrient medium for the induction of callusogenesis are 2 : 1, 2 : 2, 2 : 3 and 3 : 2 μm (Thacker et al., 2018). Regarding root regenerating plants, NAA (Smýkalová et al., 2019) or indole-3-butyric acid (Chaohua et al., 2016) are usually added to the medium.

The aim of our study was to assess the effect of exogenous growth regulators on the content of cannabinoids and the main selection traits of hemp.

Material and Methods

The plant material was a variety of industrial monoecious hemp (*Cannabis sativa* L.) of Central European type USO 31. Its plants contain non-psychotropic cannabinoid combinations and tetrahydrocannabinol (THC) within the pale of the Ukrainian law, not exceeding 0.08%. Three-year field research was carried out in northeastern Ukraine, on the southern border of the mixed forest zone, lying in the lowest part of Ukrainian Polissia. The height above the sea was 166 m, and location area coordinates are: 51°39' N and 33°59' E. The soils used for crop rotation were dark and light gray forest, slightly podzolized loams formed on moraine clay. The fertilizer application rate was $N_{120}P_{90}K_{90}$. The weather conditions during the research period (2016–2019) were various and characterized by deviations from the average annual air temperature, precipitation and relative humidity, which made it possible to comprehensively assess the content of cannabinoid compounds and the level of selection traits in different weather conditions. In the period of 2016–2019, the air temperature during the growing season was 1.5–2.1 °C higher than the long-term average. The hottest weather was in 2018. The average monthly air temperature in July was 6.5°C, and in August 6.2°C higher than the long-term average. Within four years, the amount of precipitation per month was 3–19 mm lower than the long-term average. The uneven distribution of precipitation was observed both during the month and during the growing season of hemp. In September 2016, August 2018 and August 2019, only 3.2, 2.2, 0.8 and 9.9 mm of precipitation were detected, respectively. No sharp fluctuations in relative humidity were observed, except in April and August 2016–2019, when the relative humidity was 2–5% higher than the long-term average. In general, abiotic environmental factors for the normal growth and development of hemp were particularly favorable in 2016 and 2017.

The treatment of plants in the assessment nursery (the area – 1 m^2, the number of repetitions – four) and artificially isolated areas was carried out by spraying according to the options presented in Table 1.

In order to identify the likelihood of epigenetic effects under the influence of the prolonged and repeated action of growth regulators, mature seeds were collected from treated plants in the isolated nursery, which were then resown and

the plants were treated with the appropriate stimulator for three years. After such a triple exposure, on the fourth year, the descendants were analyzed for cannabinoid content.

Table 1. Types of hemp cropper treatments with exogenous growth regulators.

Substance	Solution strength (mg/l)	Solution application rate (ml/m^2)	BBCH-scale treatment phase
Ascorbic acid (C)	400	30	BBCH 51 + BBCH 59
Nicotinic acid (PP)	200	30	BBCH 51 + BBCH 59
Succinic acid (SA)	200	30	BBCH 51 + BBCH 59
1-naphthaleneacetic acid (NAA)	20	30	BBCH 51
Indole-3-acetic acid (IAA)	200	30	BBCH 51
2,4-dichlorophenoxyacetic acid (2,4-D)	20	30	BBCH 51
Kinetin (KIN)	10	30	BBCH 51
6-benzylaminopurine (BAP)	40	30	BBCH 51
Gibberellic acid (GA_3)	100	30	BBCH 51

Note: Phenological phases of growth and development were determined by reference to the BBCH-scale (the abbreviation BBCH derives from the names of the originally participating stakeholders: "Federal Biological Institute, Federal Plant Variety Office and Chemical Industry") adapted for hemp (Mishchenko et al., 2017).

In order to identify cannabinoid compounds during the threshing of hemp plants grown in an assessment nursery with a feeding area of 30 cm × 5 cm (phase BBCH 89), a combined sample of plant material was taken from each area of 1 m^2, dried and stored at a laboratory temperature. Before the analysis, the samples were dried to constant weight at a temperature of 105 °C in an oven, ground to a fine powder and thoroughly mixed. The samples weighing 0.5 g were taken in two repetitions, and 5 ml of methanol was added (the ratio "plant type: extractant" – 1: 10). The extraction time was 24 h. After that, the extract was filtered using a paper filter. In the obtained methanol extracts of the samples, the quantitative content of cannabinoid compounds was determined by gas chromatography on an HP 6890 Series GC System chromatograph (Producer – Hewlett-Packard, USA). Chromatography conditions were: – capillary column – Agilent Technologies Inc. 19091J-413 (HP-5), length – 30 m, diameter – 0.320 mm, phase – 0.25 µm, SN: USN493366H, constant flow – 1.5 ml/min, carrier gas – helium; – injector – auto-injector 7683, Split 20 : 1, evaporator temperature – T = 250 °C; oven – $T_{initial}$ = 100°C, held for 2 minutes, heating – 15 °C/min, T_{final} = 280 °C, held for 11 minutes; – detector – flame ionization; – sample – 1.0 µl. Compounds were identified by retention time. The concentration of cannabinoids was determined using an internal standard (stearic acid methyl ester at a concentration of 0.392% of the sample).

Conditions for the microclonal propagation of hemp *in vitro* were as follows: hormonal medium Murashige and Skoog, supplemented with ascorbic acid 5 mg/l,

15 mg/l and 30 mg/l, photoperiod – 16 h, relative humidity – 60–80%, air temperature – 22–24 °C (records were performed on the 35th day of cultivation).

In the phase BBCH, 89 plants from each variant in the evaluation nursery were collected to determine selection traits: total stem length, technical stem length (distance from the root collar to the inflorescence), stem diameter (determined in the middle of the technical stem length), stem and fiber mass, fiber content, the mass of seeds from one plant, and the mass of one thousand seeds. Twenty plants were selected from all repetitions of each variant. Statistical data processing on the selection traits was performed by variation statistics methods ($\bar{x}$, $s_{\bar{x}}$, CV) using the Application Software Package "OSGE" (Ukrainian AAS, Institute of Plant Production©, TK "EliteSystems gr.", 1992, 93). The comparisons among the different treatments were made with the least significant difference (LSD) test and the Student's t-test. Statistical significance was determined at the level of $p < 0.05$.

Results and Discussion

Phytohormones, as well as vitamins and other physiologically active substances, play a very important role in plants. They have a role in the division of cells and their differentiation, forming of tissues, embryogenic processes, and ontogenesis. In addition, they influence inducible enzyme synthesis and the main vital processes of plants (breathing, water exchange, photosynthesis, excretion, etc.). Phytohormones are highly active physiologically, causing significant changes in development and growth at very low concentrations. Treating the plants with such phytohormones as NAA, IAA, 2,4-D, KIN, BAP, GA_3 and vitamins (ascorbic and nicotine acids) in the doses mentioned resulted in the change of cannabinoid content. In the variant with SA treatment, the content of cannabidiol (CBD), THC and cannabigerol (CBG), according to the three-year average, remained virtually unchanged (Table 2).

Table 2. The effect of exogenous growth regulators on the content of cannabinoid compounds (average for 2016–2018).

Variant	Content (%)		
	cannabidiol	tetrahydrocannabinol	cannabigerol
Untreated	0.1271	0.0030	0.0041
C	0.0276	0.0006	0.0021
PP	0.1419	0.0064	0.0082
SA	0.1264	0.0030	0.0040
NAA	0.0634	0.0027	0.0023
IAA	0.0461	0.0022	0.0034
2,4-D	0.2386	0.0069	0.0050
KIN	0.2173	0.0054	0.0049
BAP	0.2654	0.0044	0.0046
GA_3	0.0443	0.0010	0.0023
LSD_{05}	0.0455	0.0009	0.0009

Ascorbic acid, as an antioxidant, favored a decrease in the content of the identified compounds: CBD – with 0.1271%, and in control with near 0.0276% in the variant with processing; THC – with 0.0030%, and with near 0.0006% in the variant with processing; and CBG – with 0.0041%, and with near 0.0021% in the variant with processing, or by 78.3%, 80.0% and 48.8%, respectively, regarding the option without processing (Figure 1). Such data assert that ascorbic acid highly inhibits decarboxylation of the corresponding acidic forms of cannabinoids (CBDA, THCA and CBGA) into their neutral forms.

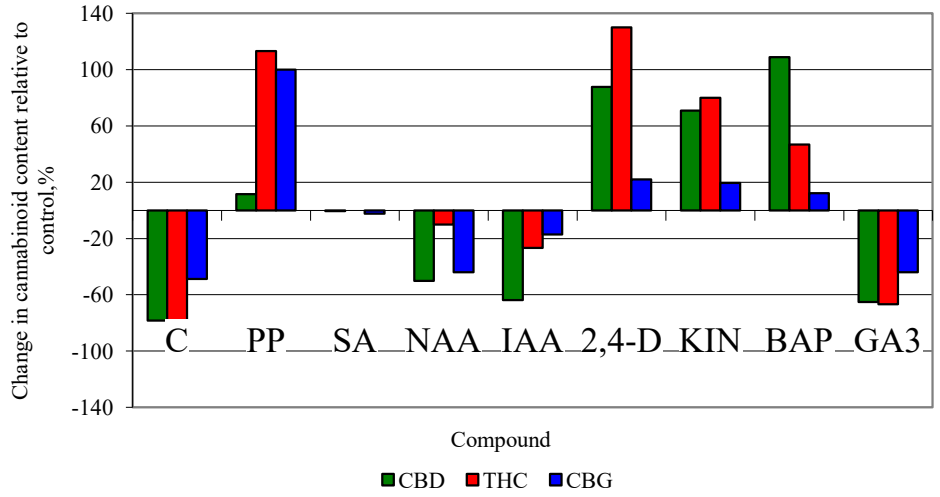

Figure 1. Changes in the content of cannabinoids in the plants of the USO 31 variety under the influence of growth regulators of exogenous origin, relative to control (+ or –), % (average for 2016–2018).

The effectiveness of hemp saturation with ascorbic acid, as an important metabolite and antioxidant, in combination with other components of the antioxidant system, for protecting plants from damage by oxidation products, is proven *in vitro*. In order to prevent the accumulation of phenolic compounds and their oxidation products, ascorbic acid was added to the nutrient medium at the concentrations of 5 mg/l, 15 mg/l and 30 mg/l. Increasing the concentration of ascorbic acid increases the length of the shoots and the number of internodes formed on them (according to average data). It also increases the efficiency of microclonal propagation, and the frequency of a positive, rapid response to cannabinoid compounds, supplemented with 30 mg/l of ascorbic acid. Therefore, in cultivating hemp *in vitro*, it is advisable to use this antioxidant to augment the efficiency of microclonal propagation (Table 2).

Table 2. The effect of ascorbic acid on the traits of hemp *in vitro.*

The concentration of C in Murashige and Skoog medium (mg/l)	Microclones				Plants with a negative reaction to cannabinoids (%)	
	length (cm)		number of internodes			
	$\bar{x} \pm s_{\bar{x}}$	CV (%)	$\bar{x} \pm s_{\bar{x}}$	CV (%)	1st passage	2nd passage
0	11.37 ± 0.710	27.9	7.0 ± 0.39	24.6	40	50
5	11.39 ± 0.847	33.2	7.3 ± 0.57	35.0	75	85
15	12.45 ± 0.668	24.0	7.4 ± 0.29	17.8	80	95
30	12.81 ± 0.421	14.7	7.9 ± 0.39	22.1	85	100

To a lesser extent, but at a reliable level of significance, the content of cannabinoid compounds was reduced by auxins (NAA and IAA) and gibberellins (GA_3). In particular, plants treated with the solution of NAA, prior to the phase of biological maturity, accumulated 0.0634% of CBD, 0.0027% of THC and 0.0023% of CBG. Plants of the variant with IOC synthesized 0.0461% of CBD, 0.0022% of THC and 0.0034% of CBG. The variant with GA_3 synthesized 0.0443%, 0.0010% and 0.0023% of the CBD, THC, and CBG. Such patterns can be explained by the fact that auxins are actively involved in the physiological mechanisms of specific hemp compound synthesis (they are inhibitors of their formation). Under the influence of gibberellins, there is a decrease in the general level of cannabinoids due to the increase in the proportion of male flowers in the inflorescence, which contain much fewer cannabinoids than the perianth of female flowers, as well as due to the increase in the total biomass of the inflorescence.

Nicotinic acid and cytokinins (2,4-D, KIN and BAP) contributed to the increase in cannabinoids. Moreover, due to the treatment with nicotinic acid, the content of THC (0.0064%) and CBG (0.0082%) increased approximately twice. As a result of exposure to 2,4-D, the content of THC approximately doubled (0.0069%). The content of CBD doubled (0.2654%) under the action of BAP, which is the largest increment value within the studied options. In addition, it was noted that, under the influence of nicotinic acid and BAP, a higher content of cannabinoid compounds is stably manifested during each of the three years of processing and is inherited by at least one generation of descendants (Table 3). Such changes cannot be explained in terms of the chromosomal theory of heredity, and they can be regarded as epigenetic only if the genotype × environment interaction is zero.

Changes of sex in hemp under the influence of photoperiod and the removal of plant tops of unisexual hybrids, created as a result of the crossing of a dioecious form of hemp with a monoecious one, have already been described (Hall et al., 2012; Mishchenko, 2018). The sex composition of F_1 hybrids grown in the field was mainly represented by female plants and a small number of monoecious plants. The sex structure shifted towards the female sex, which is fully embedded in the theory of the genotypic sex determination of hemp. Under the influence of the

reduced duration of daylight, the sexual structure of hybrids shifted towards the male sex. The content of the female plants decreased (by 36.6–92.3%), the content of monoecious sexual types increased, and male plants were observed. When combining two factors of influence – the photoperiod and the removal of growth points – this pattern was even clearer. The change in the ratio of sexual types of same-sex hybrids under the influence of photoperiod is difficult to explain in terms of the theory of the genotypic sex determination of hemp – it is epigenetic. (Mishchenko, 2018). The displayed changes in the sex of hemp flowers under the influence of external conditions are epigenetically determined, despite the fact that it is normal for this species to be identified by a syngamous method of sex determination when chromosomal sex determination is realized with a fusion of male and female gametes. Environmental conditions (or signals) allowed for regulating both the sex of hemp flowers and the reproduction system seeds, maintaining the status of sex chromosomes in the genome (Maletsky, 2008; Maletsky et al., 2013).

Table 3. Changes in the content of cannabinoid compounds in the descendants of plants treated with exogenous growth regulators for three years (2019).

Variant	Content (%)		
	cannabidiol	tetrahydrocannabinol	cannabigerol
Untreated	0.1323	0	0
C	0.1344	0	0
PP	0.1596	0.0070	0.0123
SA	0.1365	0	0
NAA	0.1310	0	0
IAA	0.1335	0	0
2,4-D	0.1402	0	0
KIN	0.1347	0	0
BAP	0.2540	0.0035	0.0115
GA_3	0.1299	0	0
LSD_{05}	0.0384		

Note: 0 – the compound was not identified within the sensitivity of the gas chromatograph and the research methods used.

From the standpoint of epigenetic effects, a promising direction to increase the level of non-psychotropic cannabinoids is the treatment of vegetative plants with cytokinin BAP, which, in contrast to high concentrations of nicotinic acid, significantly increases the content of CBD and less psychotropic THC. This technique is recommended for the use in crop production as an adjunct in the cultivation of industrial varieties of medical hemp. However, once again, it should be noted that different genotypes (varieties) may have different reactions to phytohormones and their concentrations, which must be established in each case.

The treatment of hemp plants with phytohormones, vitamins and succinic acid also affected the change of (economic) selection traits. According to the results of the control of the unprocessed plants, the total length of the plants (14.6–32.6 cm) treated with the studied compounds of the above concentration and dose significantly exceeded that of the former. GA_3 contributed to the increase of technical length at a reliable level (210.5 cm compared to 180.9 cm), which has a positive effect on increasing the quantitative and qualitative characteristics of the fiber. The variants treated with ascorbic acid had a significantly shorter technical length (163.6 cm), i.e., this compound contributed to the increase of the inflorescence size, which is positive for the increase of seed productivity. No significant difference was found for stem diameter after treatments in regard to control. There was only a tendency to its increase, especially under the influence of vitamins, SA, NAA, cytokinins (KIN and BAP) and GA_3 (Table 4).

Table 4. The variability of selection traits relating to hemp plants treated with exogenous plant growth regulators (average for 2017–2018).

Statistical indicator	Processing option									
	without processing	C	PP	SA	NAA	IAA	2,4-D	KIN	BAP	GA_3
Total length (cm)										
$\bar{x} \pm s_{\bar{x}}$	225.4±4.90	230.0±5.62	255.7±5.44	258.0±5.92	253.0±5.66	240.0±4.46	247.4±3.73	245.9±4.99	248.0±4.66	250.1±6.56
CV (%)	6.9	7.8	6.7	7.3	7.0	5.8	4.8	6.4	6.0	8.3
Technical length (cm)										
$\bar{x} \pm s_{\bar{x}}$	180.9±6.06	163.6±5.88	171.1±6.98	174.7±5.15	192.7±5.50	179.2±4.58	189.6±5.91	181.1±5.12	193.7±5.72	210.5±6.74
CV (%)	11.0	11.4	12.9	9.3	9.1	8.0	8.4	8.9	9.1	10.2
Stem diameter (mm)										
$\bar{x} \pm s_{\bar{x}}$	8.74±0.483	9.26±0.330	9.10±0.406	9.88±0.529	9.24±0.506	8.68±0.322	8.44±0.254	9.22±0.434	9.84±0.584	9.30±0.512
CV (%)	17.8	11.2	14.1	16.9	17.3	11.8	9.4	14.8	18.6	17.4
Stem mass (g)										
$\bar{x} \pm s_{\bar{x}}$	15.5±4.11	19.2±1.58	20.0±1.96	19.9±2.26	20.5±2.22	16.2±1.17	16.3±0.77	18.3±1.73	20.7±2.44	18.2±2.18
CV (%)	28.3	26.0	31.1	35.9	33.7	22.4	15.0	29.9	37.1	37.8
Fiber mass (g)										
$\bar{x} \pm s_{\bar{x}}$	4.50±0.480	6.10±0.503	5.59±0.561	5.21±0.449	6.54±0.576	5.54±0.432	4.98±0.296	5.89±0.536	6.52±0.750	5.72±0.583
CV (%)	33.5	25.8	31.7	27.2	28.6	25.2	18.8	28.8	36.6	32.2
Fiber content (%)										
$\bar{x} \pm s_{\bar{x}}$	32.6±0.67	31.4±0.81	28.3±1.15	27.0±1.12	32.6±0.66	33.1±0.50	30.7±1.19	34.4±0.82	31.4±0.79	32.6±1.02
CV (%)	6.6	8.4	12.8	13.2	6.4	5.0	11.8	8.1	8.2	9.1
Seed mass (g)										
$\bar{x} \pm s_{\bar{x}}$	4.00±0.300	3.86±0.375	5.94±0.260	5.80±0.240	6.10±0.304	4.17±0.457	3.91±0.455	3.07±0.400	4.74±0.464	3.00±0.168
CV (%)	10.6	11.2	14.3	17.1	16.9	11.8	9.4	9.9	9.9	15.5
Mass of 1000 seeds (g)										
$\bar{x} \pm s_{\bar{x}}$	16.2±0.20	18.0±0.18	18.2±0.18	17.7±0.16	18.5±0.29	18.4±0.27	18.1±0.17	17.3±0.59	17.8±0.18	16.4±0.38
CV (%)	6.5	8.5	10.0	10.0	9.1	9.2	5.0	11.5	6.2	10.1

Note: The color highlights the options that are reliably different from the control of the Student's *t*-test.

The mass of the stem also increased insignificantly under the influence of processing. Nevertheless, at the same time, the fiber mass of the plant markedly increased, in particular by more than 35% in the variants treated with ascorbic acid, NAA and BAP (6.1 g, 6.5 g and 6.5 g, respectively, compared to 4.5 g in the variant without processing). Authentically lower fiber content was formed by plants treated with ascorbic acid and nicotinic acid, namely – 28.3% and 27.0% (in the control version, this figure was 32.6%).

The control variant seed mass (4.00 g) was higher than that obtained from plants treated with nicotinic acid and succinic acid and NAA (5.94 g, 5.80 g and 6.10 g, respectively). Hemp plants treated with GA_3 of the specified concentration formed seeds with lower mass (3.00 g). It was found that many variants of the experiment were also characterized by an increased mass of a thousand seeds. The highest rate was in the variant with the NAA treatment (18.5 g compared to the control – 16.2 g).

In general, one important detail should be noted: the nature of the response to phytohormones is specific to each hemp genotype (variety) (Burgel et al., 2020).

It is known that phytohormones change the sex of hemp, but these studies are mostly conducted on dioecious hemp or varieties of monoecious hemp with unstable monoecious signs (Myhal, 2004). The influence of gibberellins and partially auxins is most widely studied, while cytokinins were ignored. Therefore, in part, this issue still remains open and relevant. Sex control is very important for selection because the combination of a large proportion of female flowers in the inflorescence and a sufficient proportion of male flowers for the normal course of the pollination process is a necessary condition for the formation of the high seed productivity of hemp.

In the modern variety of monoecious hemp, the sexual structure is represented mainly by monoecious feminized female plants (84.0% of the total), with a share of less than 30% of male flowers in the inflorescence. When the 2,4-D trea tment was carried out, the action of phytohormone occasioned a shift of signs towards the female sex, in particular, 95.4% of monoecious feminized female plants were taken into account. The treatment with BAP, NAA, IAA, KIN and ascorbic acid caused a decrease in the number of monoecious feminized female plants with a small proportion of male flowers in the inflorescence – 85.0%, 75.0%, 73.5%, 72.8% and 59.4%, respectively, and an increase in the number of other sexual types. As a result of the GC_3 treatment, there was a shift of signs towards the male sex. The sexual structure was represented mainly by monoecious plants with a predominance of male flowers in the inflorescence. Nicotinic acid and SA contributed to the shift of the sexual structure towards the female sex (up to 100.0% in the first variant) (Figure 2).

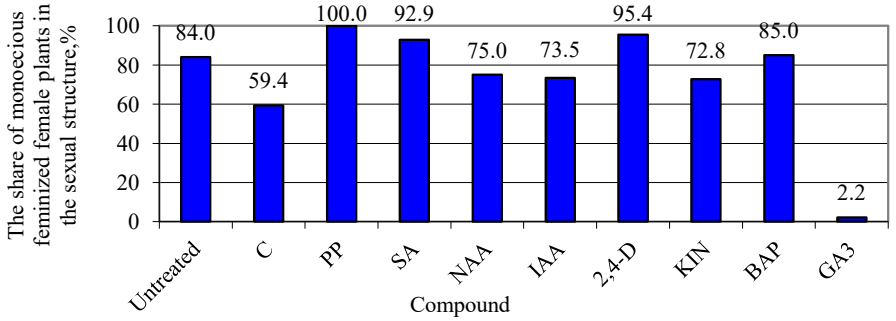

Figure 2. The influence of exogenous growth regulators on the formation of the sexual structure of hemp population (average for 2017–2018).

Plant growth regulators are successfully used in crop production to regulate plant morphogenesis, productivity and to control the biochemical composition of products, such as wheat (Iqbal and Ashraf, 2013), potatoes (Rogach and Rogach, 2015; Rogach et al., 2016), eggplant (Rogach et al., 2020), sweet pepper (Rogach et al., 2021), sugarcane (Qiu et al., 2019), coriander (Saleem et al., 2021), etc. Accordingly, there are wide opportunities for the use of phytohormones of exogenous origin in the regulation of cannabinoid accumulation and in the formation of valuable economic characteristics and productivity of hemp.

Conclusion

Hemp (*Cannabis sativa* L.) is a species sensitive to the effects of phytohormones, vitamins and other physiologically active substances. In plants of the variety USO 31, ascorbic acid as an antioxidant, auxins and GA_3 significantly reduced the content of cannabinoids, whereas nicotinic acid and cytokinins increased it. As a result of triple exposure to nicotinic acid and BAP, changes in the descendants persisted. An additional method to increase the level of non-psychotropic cannabinoids may be the treatment of vegetative plants with cytokinin BAP, which, in contrast to high concentrations of nicotinic acid, significantly increases the content of CBD and, to a lesser extent, THC. The selection traits such as stem total length, mass and fiber content, seed productivity and sex underwent the biggest changes under stimulator treatments. Different genotypes of hemp may have different reactions to phytohormones and their concentrations, which should be established in each case.

References

Ačko, D.K., Flajšman, M., & Trdan, S. (2019). Apical bud removal increased seed yield in hemp (*Cannabis sativa* L.). *Acta Agriculturae Scandinavica, Section B – Soil & Plant Science, 69* (4), 317-323.

Brockman, H.G., Brennan, R.F., & van Burgel, A. (2020). The impact of phytohormone concentration in *Moringa oleifera* leaf extract on wheat yield and components of yield. *Journal of Plant Nutrition, 43* (3), 396-406.

Burgel, L., Hartung, J., Schibano, D., & Graeff-Hönninger, S. (2020). Impact of different phytohormones on morphology, yield and cannabinoid content of *Cannabis sativa* L. *Plants*, *9* (6), 725.

Chaohua, C., Gonggu, Z., Lining, Z., Chunshenget, G., Qing, T., Jianhua, C., Xinbo, G., Dingxiang, P., & Jianguang, S. (2016). A rapid shoot regeneration protocol from the cotyledons of hemp (*Cannabis sativa* L.). *Industrial Crops and Products, 83*, 61-65.

Galán-Ávila, A., García-Fortea, E., Prohens, J., & Herraiz, F.J. (2020). Development of a direct *in vitro* plant regeneration protocol from *Cannabis sativa* L. seedling explants: developmental morphology of shoot regeneration and ploidy level of regenerated plants. *Frontiers in Plant Science, 11*, 645.

Hall, J., Bhattarai, S.P., & Midmore, D.J. (2012). Review of flowering control in industrial hemp. *Journal of Natural Fibres, 9* (1), 23-36.

Ilyas, M., Nisar, M., Khan, N., Hazrat, A., Khan, A.H., Hayat, K., Fahad, S., Khan, A., & Ullah, A. (2021). Drought tolerance strategies in plants: a mechanistic approach. *Journal of Plant Growth Regulation*, *40* (3), 926-944.

Iqbal, M., & Ashraf, M. (2013). Gibberellic acid mediated induction of salt tolerance in wheat plants: Growth, ionic partitioning, photosynthesis, yield and hormonal homeostasis. *Environmental and Experimental Botany*, *86,* 76-85.

Kumlay, A.M. (2014). Combination of the auxins NAA, IBA, and IAA with GA_3 improves the commercial seed-tuber production of potato (*Solanum tuberosum* L.) under *in vitro* conditions. *BioMed Research International, 2014*, 439259.

Lata, H., Chandra, S., Techen, N., Khan, I.A., & ElSohly, M.A. (2016). *In vitro* mass propagation of *Cannabis sativa* L.: a protocol refinement using novel aromatic cytokinin meta-topolin and the assessment of eco-physiological, biochemical and genetic fidelity of micropropagated plants. *Journal of Applied Research on Medicinal and Aromatic Plants, 3* (1), 18-26.

Maletsky, S.I. (2008). Epigenetic variability of flower sex and creation on its basis of monoecious cultivars of hemp (*Cannabis sativa* L.). *Plant Introduction, 1,* 100-113. [in Russian]

Maletsky, S.I., Roik, N.V., & Dragavtsev, V.A. (2013). Third variability, the inheritance types and seed reproduction in plants. *Agricultural Biology, 5*, 3-29. [in Russian]

Mendel, P., Schiavo-Capri, E., Lalge, A.B., Vyhnanek, T., Kalousek, P., Trojan, V., Havel, L., Filippi, A., & Braidot, E. (2020). Evaluation of selected characteristics in industrial hemp after phytohormonal treatment. *Pakistan Journal of Agricultural Sciences, 57* (1), 1-7.

Myhal, M.D. (2004). *Experimental change of hemp sex.* Sumy: SOD. [in Ukrainian]

Mishchenko, S., Mokher, J., Laiko, I., Burbulis, N., Kyrychenko, H., & Dudukova, S. (2017). Phenological growth stages of hemp (*Cannabis sativa* L.): codification and description according to the BBCH scale. *Žemės ūkio mokslai*, *24* (2), 31-36.

Mishchenko, S.V. (2018). Epigenetic determined sex change of the hemp unisexual hybrids under the influence of photoperiod. *Plant Breeding and Seed Productivity, 113*, 102-110. [in Ukrainian]

Neumann, K.H., Kumar, A., & Imani, J. (2020). Phytohormones and growth regulators. In *Plant Cell and Tissue Culture – A Tool in Biotechnology* (pp. 309–320). Cham: Springer. Qiu, L.-H., Chen, R.-F., Luo, H.-M., Fan, Y.-G., Huang, X., Liu, J.-X., Xiong, F.-Q., Zhou, H.-W., Gan, C.-K., Wu, J.-M., & Li, Y.-R. (2019). Effects of exogenous GA_3 and DPC treatments on levels

of endogenous hormone and expression of key gibberellin biosynthesis pathway genes during stem elongation in sugarcane. *Sugar Tech, 21*, 936-948.

Rogach, V.V., & Rogach T.I. (2015). Influence of synthetic growth stimulators on morphological and physiological characteristics and biological productivity of potato culture. *Visnyk of Dnipropetrovsk University. Biology, ecology, 23* (2), 221-224. [in Ukrainian]

Rogach, V.V., Poprotska, I.V., & Kuryata, V.G. (2016). Effect of gibberellin and retardants on morphogenesis, photosynthetic apparatus and productivity of the potato. *Visnyk of Dnipropetrovsk University. Biology, ecology, 24* (2), 416-420. [in Ukrainian]

Rogach, V.V., Voytenko, L.V., Shcherbatiuk, M.M., Rogach, T.I., & Kosakivska, I.V. (2020). Effect of foliar treatment with synthetic growth regulators on morphogenesis, content of pigments and phytohormones, and productivity of *Solanum melongena* L. *Bulletin of Kharkiv National Agrarian University. Series Biology*, *2* (50), 105-118. [in Ukrainian]

Rogach, V.V., Voytenko, L.V., Shcherbatiuk, M.M., Kuryata, V.G., Kosakivska, I.V., & Rogach T.I. (2021). Effects of exogenous plant growth regulators on morphogenesis, physiological and biochemical characteristics, and productivity of sweet pepper *Capsicum annuum* L. *Plant Physiology and Genetics, 53* (4), 320-335. [in Ukrainian]

Saleem, M.H., Wang, X., Ali, S., Zafar, S., Nawaz, M., Adnan, M., Fahad, S., Shah, A., Alyemeni, M.N., Hefft, D.I., & Ali, S. (2021). Interactive effects of gibberellic acid and NPK on morpho-physio-biochemical traits and organic acid exudation pattern in coriander (*Coriandrum sativum* L.) grown in soil artificially spiked with boron. *Plant Physiology and Biochemistry, 167,* 884-900.

Sauer, M., Robert, S., & Kleine-Vehn, J. (2013). Auxin: simply complicated. *Journal of Experimental Botany*, *64* (9), 2565-2577.

Smýkalová, I., Vrbová, M., Cvečková, M., Plačková, L., Žukauskaitė, A., Zatloukal, M., Hrdlička, J., Plíhalová, L., Doležal, K., & Griga, M. (2019). The effects of novel synthetic cytokinin derivatives and endogenous cytokinins on the *in vitro* growth responses of hemp (*Cannabis sativa* L.) explants. *Plant Cell, Tissue and Organ Culture, 139* (2), 381-394.

Sudan, P., Sudan, S., Behl, T., Sharma, M., & Misri, R.W. (2014). A critical insight into the intricate role of plant hormones in growth and development phase. *PharmaTutor*, *2* (4), 87-89.

Thacker, X., Thomas, K., Fuller, M., Smith, S. & DuBois, J. (2018). Determination of optimal hormone and mineral salts levels in tissue culture media for callus induction and growth of industrial hemp (*Cannabis sativa* L.). *Agricultural Sciences, 9* (10), 1250-1268.

Ullah, A., Manghwar, H., Shaban, M., Khan, A. H., Akbar, A., Ali, U., Ali, E., & Fahad, S. (2018). Phytohormones enhanced drought tolerance in plants: a coping strategy. *Environmental Science and Pollution Research, 25* (33), 33103-33118.

Wróbel, T., Dreger, M., Wielgus, K., & Słomski, R. (2018). The application of plant in vitro cultures in cannabinoid production. *Biotechnology Letters, 40* (3), 445-454.

Received: December 21, 2021
Accepted: July 4, 2022

UTICAJ EGZOGENIH REGULATORA RASTA NA SADRŽAJ KANABINOIDA I GLAVNE SELEKCIONE OSOBINE KONOPLJE (*CANNABIS SATIVA* L. SSP. *SATIVA*)

Serhii V. Mishchenko[1], Iryna M. Laiko[1], Serhiy M. Tkachenko[1], Yurii O. Lavrynenko[2], Tetiana Y. Marchenko[2] i Olena O. Piliarska[2*]

[1]Institut za tekstilne useve Nacionalne akademije agrarnih nauka Ukrajine, 45 Tereshchenkiv, Gluhiv, Sumska oblast, 41400, Ukrajina
[2]Institut za navodnjavanu poljoprivredu Nacionalne akademije agrarnih nauka Ukrajine, Nadniprjanske, Herson, 73483, Ukrajina

R e z i m e

Konoplja (*Cannabis sativa* L.) je vrsta osetljiva na uticaj egzogenih regulatora rasta, kako kod tretiranja vegetativnih biljnih tkiva, tako i kod kultura *in vitro.* 1-naftilsićetna kiselina, indol-3-sirćetna kiselina, 2,4-dihlorofenoksisirćetna kiselina, kinetin, 6-benzilaminopurin (BAP), giberelinska kiselina (GA_3), askorbinska kiselina i nikotinska kiselina egzogenog porekla u ispitivanim koncentracijama i dozama izazvali su promenu sadržaja kanabinoida kod biljka sorte USO 31. Askorbinska kiselina, auksini i GA_3 značajno su smanjili sadržaj kanabinoida, dok su ga nikotinska kiselina i citokinini povećali. Pod uticajem nikotinske kiseline i BAP-a, veći sadržaj kanabinoidnih jedinjenja se stabilno ispoljavao tokom svake od tri godine prerade i nasleđuje ga najmanje jedna generacija potomaka. Dodatna metoda za povećanje nivoa nepsihotropnih kanabinoida može biti tretiranje vegetativnih biljnih tkiva citokininom BAP (koncentracije 40 mg/l, sa stopom unosa 30 ml/m^2, u fazi rasta i razvoja-BBCH 51), koji je, za razliku od visokih koncentracija nikotinske kiseline, značajno povećao sadržaj kanabidiola, a u manjoj meri i tetrahidrokanabinola. Selekcione osobine konoplje – ukupna dužina stabljike, masa i sadržaj vlakana, produktivnost semena i determinacija pola značajno su se povećali tokom tretmana. Potvrđen je širok spektar mogućnosti za upotrebu fitohormona egzogenog porekla u regulisanju akumulacije kanabinoida, morfogeneze biljaka konoplje i njihove produktivnosti. Različiti genotipovi konoplje mogu imati različite odgovore na regulatore rasta biljaka u različitim koncentracijama, što treba utvrditi u svakom slučaju.

Ključne reči: konoplja, fitohormoni, vitamini, kanabinoidi, produktivnost, determinacija pola.

Primljeno: 21. decembra 2021.
Odobreno: 4. jula 2022.

[*]Autor za kontakt: e-mail: izz.biblio@ukr.net

Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2203253A
Vol. 67, No. 3, 2022 UDC: 633.524.2(669)
Pages 253-267 Original scientific paper

THE APPROPRIATE PLANTING TIME FOR THE PROFITABLE PRODUCTION OF THE QUALITY SEED OF KENAF (*HIBISCUS CANABINUS* L.) IN SOUTHWESTERN NIGERIA

Johnson A. Adetumbi*, Dotun J. Ogunniyan, Sikiru Ajijola, Ajoke Oyegbami and Olutayo N. Adeniyan

Institute of Agricultural Research and Training, Obafemi Awolowo University, Ibadan, Oyo State, Nigeria

Abstract: The low seed yield of kenaf in different agro-ecologies in southwestern Nigeria has been partly attributed to the effect of climate change. An experiment was, therefore, conducted to determine the response of kenaf to prevailing weather conditions and the most appropriate planting time to produce optimum seed yield of acceptable quality that will be profitable in humid agro-ecologies of Nigeria. The study was conducted at five research stations (Ibadan, Ilora, Ikenne, Orin Ekiti and Kishi) of the Institute of Agricultural Research and Training (I.A.R.&T) in Ibadan, Nigeria, in the 2018 and 2019 planting seasons (June to August). Seeds of five varieties of kenaf (Cuba108, Ifeken DI 400, Ifeken100, Ifeken 400 and Tianung-2) were planted at monthly interval between June and August of each year in a randomised complete block design (RCBD) with three replicates. Harvesting, threshing and cleaning were manually done, and samples of clean seeds were analysed for seed quality. Data were obtained on plant height at harvest, seed yield-related traits and seed quality parameters. Profitability analysis was also conducted to estimate the cost and returns to production in the different locations. Kenaf seed yield and quality were highly influenced by the production environment. It is concluded that planting of kenaf in mid-June in southwestern Nigeria will give optimum seed yield of high quality with profitable gross return on investment.

Key words: kenaf, sowing date, quality seed, humid agro-ecology.

Introduction

Kenaf (*Hibiscus canabinus* L.) is an annual fibre crop that is closely related to cotton (*Gossypium hirssutum* L.) and okra (*Abelmoschus esculentus* L.) (Amusat and Ademola, 2014). It is the third largest fibre crop of economic importance after cotton and jute. The crop, which has numerous potentials that can enhance the

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

economy of developing countries through diverse uses of its fibre, is commercially cultivated in some Asian countries like India, China, Thailand and Vietnam (Olasoji et al., 2014). Although the multi-purpose uses of kenaf are gradually increasing its demand, the scarcity of the quality seed of the crop has been reported as a major limiting factor in the expansion of its production at the commercial level. In Bangladesh, the shortage of the supply of quality seeds of kenaf has been attributed to the inadequate knowledge of farmers regarding seed production technology (Mollah et al., 2015). This has resulted in the use of low quality seeds in the country and other parts of Africa.

The main products of kenaf are core and bast fibres. However, the production of acceptable high-quality fibre for industrial uses cannot be combined with seed production as the process for obtaining the two products differs. Seed production of kenaf requires adequate attention and a longer time than cultivation for fibre. In most developing countries where kenaf is produced, farmers are not well equipped with the technological requirements for commercial quality seed production of the crop, hence the crop is currently grown as a subsistence crop in Nigeria. There is a renewed interest of the government in the production of kenaf for fibre in Nigeria. Therefore, farmers are increasingly becoming aware of its economic potentials, making it gradually become a major crop in the country (Ogunniyan, 2016), and thereby increasing the demand for quality kenaf seeds across the country.

Kenaf has high adaptability to various growing environments, and its cultivation is easy (LeMahieu et al., 2003). However, recent efforts to produce kenaf seeds in different agro-ecologies in southwestern Nigeria resulted in low seed yield than expected. This could be attributed to several reasons, among which is the effect of climate change on the crop. The flowering was delayed and irregular, while the capsule formation was poor. Kenaf can be photosensitive, thus it will respond to the time of planting, which can be influenced by climate change. Consequently, it becomes pertinent to determine the response of the crop to prevailing weather conditions and the most appropriate planting time for the crop to produce optimum seed yield of acceptable quality. This study was, therefore, conducted to determine the appropriate planting time for optimum quality kenaf seed yield, as well as the profitability of the seed production in humid agro-ecologies of Nigeria to provide information that will encourage the private sector involvement in kenaf seed production.

Material and Methods

Experimental locations

The study was conducted at five research stations of the Institute of Agricultural Research and Training (I.A.R. &T) in Ibadan, Nigeria, in the 2018 and 2019 planting seasons. The stations are located in Ibadan (transitional-rain forest),

Ilora (derived savannah), Ikenne (high rain forest), Orin Ekiti (rain forest) and Kishi (southern guinea savannah) (Figure 1). The rainfall records in terms of the number of rain days and volume were obtained from the meteorological stations in each location.

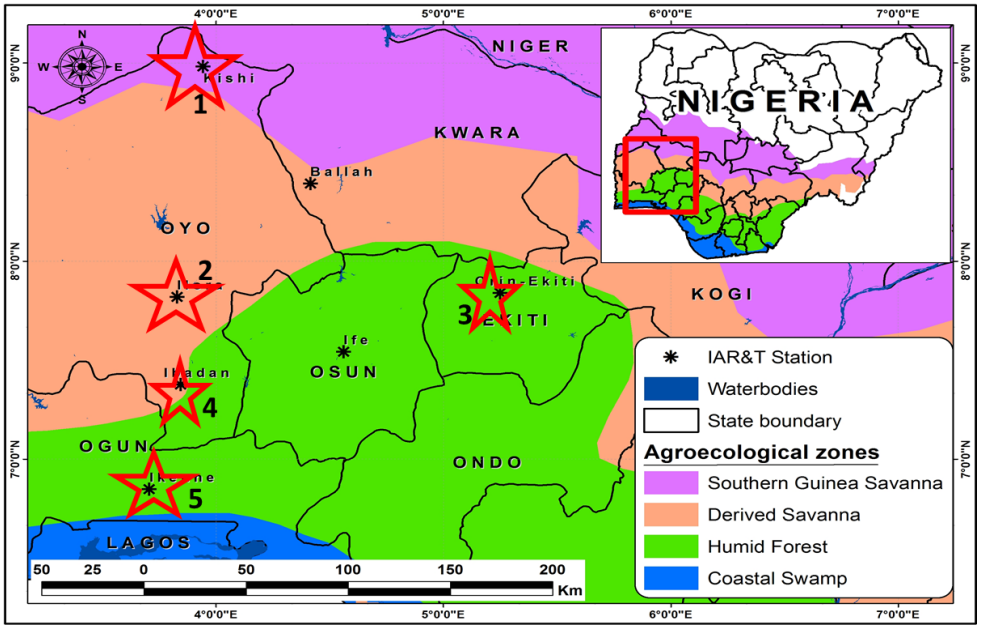

Figure 1. The geographical location of the experimental sites.
1: Kishi, 2: Ilora, 3: Orin Ekiti, 4: Ibadan, 5: Ikenne.

Field experiments and experimental designs

Seeds of five varieties of kenaf (Cuba108, Ifeken DI 400, Ifeken100, Ifeken 400 and Tianung-2) were planted at a spacing of 50 cm x 20 cm at monthly intervals from June to August (June 10, July 10 and August 10) of 2018 and 2019. The plot size was 5 m by 5 m, resulting in 180 plants per plot. The experimental design was a randomised complete block design (RCBD) with three replicates. Four seeds were planted per hole and later thinned to two plants per stand at 2 weeks after planting (WAP). Weed control was done through the application of pre-emergence herbicide (Pendimethalin 500 EC) at the rate of 2.0 kg ha^{-1}a.i. Supplementary weeding was done manually at 5 WAP. The NPK-20-10-10 fertiliser was applied immediately after the manual weeding at the rate of 300kg ha^{-1}, while urea was applied to top dress the plants at 10 WAP at the rate of 200kg ha^{-1} in both years. Insects were controlled with Cypermethrin+Dimethoate ® applied at

the rate of 20ml/20 litres of water, sprayed three times at 2-week intervals, beginning from 5 WAP, when the plants attained 50% flowering until when capsules were well formed. Harvesting of the plant was manually done at about 5 months after planting when 80% of the capsules became brown. Thereafter, the capsules were sun-dried for three days, threshed and cleaned to obtain the seeds. Clean seeds were then bagged into hessian sack bags, and samples were taken. The quality analysis was conducted in the seed testing laboratory of IAR&T, Ibadan, Nigeria, using the procedure of International Seed Testing Association (ISTA, 2003).

Ten plants were randomly selected and tagged within the three inner rows to obtain the following agronomic data:

i. Plant height at harvest: Measured with a steel meter ruler from the ground level to the highest point (cm). The average height of the 10 tagged plants was recorded as plant height;

ii. The number of capsules per plant: The average number of capsules counted from the 10 tagged plants per plot;

iii. The number of seeds per capsule: The average number of seeds counted from 10 randomly selected capsules from the total capsules in each plot;

iv. Seed weight per capsule (g): The average weight of seeds from 10 randomly selected capsules in each plot;

v. Seed yield per plant (g): The average value of seed weight from 10 randomly selected plants per plot;

vi. Seed yield/plot (g): The weight of total seeds from each plot;

vii. 100-seed weight (g): The weight of one hundred seeds taken randomly in three replicates from the threshed seeds and weighed using a sensitive Seedburo™ laboratory scale model 9000AG/A. The average of the three replicates was recorded for each plot;

viii. Seed yield per hectare (kg): Calculated from the seed weight per plot, the number of plants per plot at harvest and expected plant population per hectare and a constant factor of 1000 to convert gramme to kilogram. The calculation was done using the following formula:

Seed yield per hectare =

$$\left[\frac{Seed\ weigth\ per\ plot\ (g)}{Number\ of\ plants\ per\ plot}\right] \text{ x } \left[\frac{Plant\ population\ /\ hectare}{1000}\right] \quad (1)$$

where plant population per hectare was calculated as:

$$\text{Plant population} = \frac{Land\ area}{Plant\ Spacing} x \frac{Number\ of\ plants\ per\ stand}{1} \quad (2)$$

Seed quality assessment

The samples of the harvested seed from each location for each planting time were evaluated for seed viability and seedling vigour. Seed viability was

determined by placing three sub-samples of 100 seeds each on sterilised river sand that was adequately moistened with 300ml of distilled water and allowed to germinate at room temperature.

The germination counts were done on 3, 5, and 7 DAP. The final count was done on the 7th day of planting as described by Adetumbi et al. (2019):

$$\text{Seed viability} = \frac{\textit{Number of normal seedlings}}{\textit{Number of seeds planted}} \; x\; 100 \qquad (3)$$

The seedling vigour index (SVI) was evaluated on the seventh day of planting as the product of seed viability (%) and seedling length at 7 DAP using the formula:

$$\text{SVI} = \frac{(\textit{Seed viability x Seedling length})}{100} \text{ (Adetumbi et al., 2019).} \qquad (4)$$

The mean germination time (MGT) represents the average number of days taken for all the viable seeds to germinate. It was calculated based on the modified method described by Al-Mudaris (1998) as $\text{MGT} = \frac{\sum fx}{\sum f}$ where f is the number of seeds germinated on day x.

Economic performance evaluation

The market valuation of yield components using adjusted yield per hectare at a current market price of kenaf seeds, associated cost of production comprising labour cost, input purchases and other expenses were noted and used to conduct a partial budgeting analysis. The associated cost of the production differed from location to location. Therefore, the cumulative gross margin and net benefit associated with production costs were calculated and compared among treatments and locations. The profitability analysis was conducted to estimate the costs and returns to production in the different locations. The gross margin analysis is expressed as: gross margin (GM) = TR – TVC, where TR = total revenue and TVC = total variable cost.

Data analysis

The collected data were analysed for each year with SAS using the General Linear Model (GLM) procedure, and significant means were separated using Duncan's Multiple Range Test (DMRT) at a 5% probability level. Correlation analysis was used to determine the relationship between plant height and seed yield attributes of kenaf.

Results and Discussion

Distribution of rainfall during the experiment

The rainfall distribution patterns of the two years, 2018 and 2019, were erratic and unpredictable (Figures 2 and 3). In all the locations, the amount of rainfall reduced drastically in November, with a total stoppage in December. Rainfall was more erratic in 2018 than in 2019. In June 2018, Ilora (derived savannah) recorded the highest rainfall while Ikenne (rain forest ecology) recorded the lowest. The Ibadan station site, located in a transitional savannah ecology, had the highest amount of rainfall in August 2018, while all other locations experienced the usual August break. However, in June 2019, rainfall recorded in Ikenne (rain forest ecology) was higher than in all other locations. The volume of the rainfall declined towards August before getting to its climax in October 2019. Global effects of climate that are characterised by variations in the seasonal amount, timing, distribution and intensity of precipitation are a reality. These varying factors have a significant impact on crop productivity, especially in Africa, where over 80% of total agriculture in Africa is rain-fed (Gornal et al., 2010).

Rainfall is one of the most important criteria used for the objective analysis of climatic variations over time (Murumkar et al., 2013). The unpredictable and erratic weather situation is evident in the rainfall pattern recorded in the five locations during the two seasons. Contrary to the expectation that the amount of rainfall in the savannah will be lower than in forest ecologies, the rainfall recorded in 2018 at Ilora (derived savannah) was higher than in Orin Ekiti (rainforest ecology). The varied changing rainfall pattern of the two years is an indication of the year-to-year variability of the rainfall pattern with an overall negative effect on crop yield. This confirms the earlier assertion of Huho et al. (2012) on a general effect of rainfall patterns on agricultural productivity. The amount of rainfall recorded in each location revealed that the rainfall pattern of each location differed within the two years of the study.

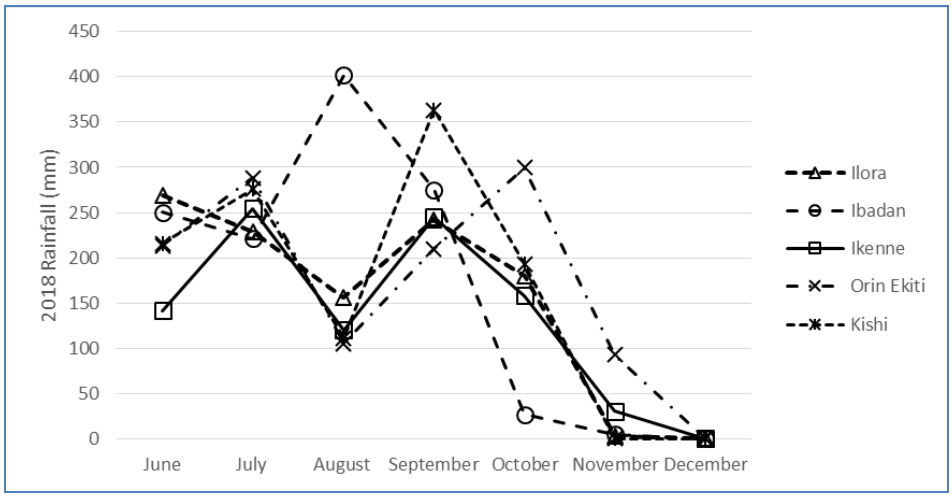

Figure 2. The rainfall distribution pattern during the experiment in 2018.

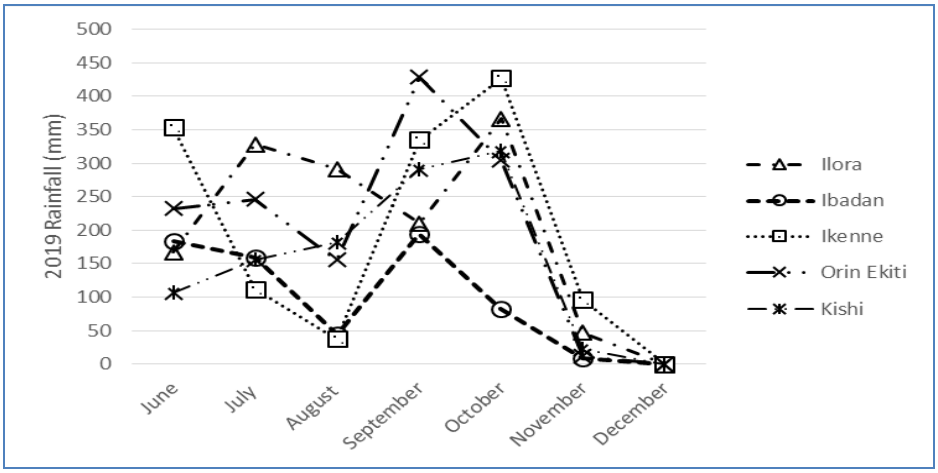

Figure 3. The rainfall distribution pattern during the experiment in 2019.

Means of seed yield and the quality of kenaf as affected by planting times and locations

Means from the analysis of variance (ANOVA) are presented in Table 1. All the seed yield and quality parameters of kenaf were significantly affected by planting times and locations ($p \leq 0.05$). There was also a significant difference in most of the results obtained during the two years of evaluation, except for seed weight per plant and seed yield per hectare. There was no significant difference among the varieties in all the variables except for the seedling vigour index. The

interaction means of location and planting time (L × P) as well as year and location (Y × L) were significant ($p \leq 0.05$) for all the variables. However, the interaction means of location and variety (L × V) were significant for the number of capsules per plant and all seed quality parameters, such as seed viability, seedling vigour index and mean germination time only.

Seed yield and quality parameters of kenaf as affected by planting locations

Some of the seed yield parameters of kenaf planted in Ilora, including the number of seeds per capsule (21), seed weight per plant (7.1 g) and seed weight per plot (350.6 g), were significantly higher than in all other locations (Table 2). The number of capsules per plant (43) and seed yield per hectare (708.8 kg) in Ilora were not significantly different from the number of capsules of kenaf in Kishi (41) and seed yield per hectare in Orin Ekiti (644.7 kg) (Table 2). The SVI and MGT of kenaf seeds in Ilora and Orin Ekiti were significantly similar. On the contrary, the seed viability in Orin Ekiti (74.4%) was significantly higher than in all other locations, followed by the seed viability in Ilora (68.3), while the seeds of plants in Ikenne had the lowest (53.1) viability (Table 2). The significant influence of locations on the plant height, seed yield and quality of kenaf may be attributed to the difference in the rainfall pattern of each location. Kyei-Mensah et al. (2019) have reported that rainfall is a major natural occurrence that is indispensable in crop and food production, especially in the developing world. Akinrotimi and Okocha (2018) have also associated seasonal variations in kenaf seed yield planted in southeastern Nigeria to variations in rainfall patterns. Kenaf planted in savannah agro-ecologies (Ilora and Kishi) recorded high plant height in July and August due to the high exposure to solar radiation with an adequate water supply in the savannah during the trial. However, the plants in the forest agro-ecology recorded high plant height when planted in June as a response to the availability of soil and environmental moisture. Lee et al. (2017) have reported that vegetative and reproductive growths of *Epilobium hirsutum L*. are accelerated with the increase in moisture and organic matter content in the soil. Ogunniyan et al. (2016) have also reported that kenaf is sensitive to the amount of rainfall, especially during the vegetative growth. The significant effect of production environments and months on the quality of kenaf seed is an indication of the sensitivity of kenaf seeds to the weather situation. This may be connected to the constituent of the kenaf seed. Most of the seeds with high oil content have been reported to have physiological changes caused by enzymatic reactions within the seeds in reaction to the environmental situation (Catao et al., 2018). The oil content in kenaf seed ranges from 21.4% to 26.4% (Muhamed et al., 1995), thus the reaction of the oil within the seed to the environmental situation can trigger deterioration in the face of slightly unfavourable weather conditions.

Table 1. Means squares of analysis of variance (ANOVA) for kenaf seed yield and quality components as affected by varieties, planting dates and locations.

Source	df	Plant height	No. of capsules per plant	No. of seeds per capsule	Seed wt. per plant
Location (L)	4	122179.7*	5418.5*	1467.43*	281.95*
Planting time (P)	2	44604.9*	10350.2*	1644.74*	1742.36*
Replicate	2	212.6	23.6	49.31*	5.96
Variety (V)	4	295.2	92.5	8.16	12.02
Year (Y)	1	670991.9*	5356.1*	383.62*	3.48
L X P	8	28486.7*	1464.7*	132.32*	80.95*
L X V	16	249.6	162.9*	9.68	11.9
Y X L	4	11758.3*	4562.8*	143.46*	132.54*
P X V	8	321.8	61.6	12.78	7.83
Y X P	2	40123.9*	133.6	46.42*	439.58*
Y X V	4	1165.6*	63.4	29.18	2.81
L X P X V	32	281.2	119.0*	10.35	9.33
Y X L X P	8	24142.2*	705.8*	120.63*	82.45*
Y X L X V	16	693.7	113.5	8.97	9.88
Y X P X V	8	289.1	42.8	13.52	6.05
Error	327	480.7	79.3	12.83	8.01

Continued Table 1. Means squares of analysis of variance (ANOVA) for kenaf seed yield and quality components as affected by varieties, planting dates and locations.

Source	Total seed weight	Seed yield/ha	SVI	Seed viability	MGT
Location (L)	1070388.94*	2819588.36*	140.47*	5736.44*	26.05*
Planting time (P)	4781856.96*	17423651.81*	911.59*	30328.78*	60.79*
Replicate	6715.41	59665.39	1.31	107.88	0.07
Variety (V)	11791.2	120250.33	11.15*	214.91	0.37
Year (Y)	1555006.09*	34828.79	303.78*	6905.47*	58.20*
L X P	653578.58*	809537.99*	70.15*	2178.6*	36.89*
L X V	11479.21	119047.75	6.21*	305.37*	0.93*
Y X L	681656.83*	1325409.12*	12.79*	743.48*	5.44*
P X V	11774.99	78341.37	5.31*	173.29	1.12*
Y X P	292406.07*	4395889.37*	166.88*	5237.47*	10.93*
Y X V	18997.61	28111.05	2.02	99.91	1.05*
L X P X V	12787.61	93317.57	6.09*	214.74*	0.75*
Y X L X P	296074.94*	824531.67*	100.34*	3585.43*	3.40*
Y X L X V	12132.33	98821.15	6.67*	198.62*	0.86*
Y X P X V	24812.44*	60524.98	3.46	106.79	0.72
Error	10484.66	80056.70	2.70	100.41	0.42
Location (L)	1070388.94*	2819588.36*	140.47*	5736.44*	26.05*

Table 2. Location effects on kenaf seed yield and quality components.

Location	Plant height	No. of capsules per plant	No. of seeds per capsule	Seed wt. per plant (g)	Seed weight/plot (g)	Seed yield/ha (kg)	SVI	Seed viability	MGT
Kishi	211.5[a]	41a	20b	4.2c	257.81b	418.9c	3.3b	61.3d	2.7c
Ilora	159.0b	43a	21a	7.1a	350.62a	708.8a	4.6a	68.3b	3.7ab
Orin-Ekiti	140.4c	25c	15c	6.4a	117.30c	644.7a	5.1a	74.4a	3.5ab
Ikenne	121.4d	35b	11d	2.7d	96.05c	268.1d	1.9c	53.1e	2.5c
Ibadan	120.8d	27c	19b	5.4b	276.32b	541.2b	3.7b	64.6c	3.3b

SVI: Seedling vigour index, MGT: Mean germination time (days).

Seed yield and quality parameters of kenaf as affected by planting times

All the seed parameters of kenaf planted in June were significantly higher than in other months, except for mean germination time (3.4). The kenaf planted in August recorded the significantly lowest seed yield and all the seed quality parameters (Table 3). The seed yield of kenaf planted in June was the highest, regardless of the locations, while August planting gave the lowest seed yield in all the locations. This result indicates that June plants received the required precipitation that enhanced plant growth and seed production. Kenaf is a photosensitive plant whose flowering pattern is a major determinant of the quantity and quality of produced seeds. The amount of water received through rainfall by the plants planted in August during the flowering period could cause flower abortion in the plants. In all the locations, rainfall reached the second peak when the plants were either preparing to flower or had already flowered. A similar result was recorded in Ibadan in 2015 by Olanipekun and Togun (2020).

Table 3. Planting time effects on kenaf seed yield and quality components.

Planting time	Plant height	No. of capsules per plant	No. of seeds per capsule	Seed wt. per plant	Total seed weight	Seed yield/ha	SVI	Seed viability	MGT
June	168.4a	40a	20a	8.4a	412.5a	842.5a	6.3a	79.1a	3.4b
July	150.2b	38a	18b	5.4b	186.1b	543.9b	3.4b	63.2b	3.7a
August	133.9c	25b	14c	1.6c	60.2c	162.6c	1.4c	40.7c	2.4c

SVI: Seedling vigour index, MGT: Mean germination time (days).

Interactive effects of planting locations and planting times on the plant height, seed yield and quality of kenaf

The interactive effects of locations and planting times on the plant height, seed yield and quality of kenaf are presented in Table 4. The plant height of kenaf

planted in June was higher in the forest agro-ecology (Ikenne and Orin Ekiti) and the transitional ecology (Ibadan), while the plant height of kenaf planted in August was higher in Ilora (derived savannah) and Kisi (southern guinea savannah). The seed yield was the highest in June in all the locations. The highest seed yield (1611 kg ha^{-1}) was obtained from kenaf planted in June in Ilora, followed by Orin Ekiti (1431.5 kg ha^{-1}), while the lowest seed yield (296.5kg ha^{-1}) was recorded in Ikenne. The quality of seed as measured by viability and seedling vigour index of kenaf planted in June was higher than in all other months in all the locations. Seeds of kenaf plants in Ilora recorded the highest seed viability (97%) and SVI (10.1), while seeds in Ibadan recorded the second highest viability (89%) but the lowest SVI (7.5). The mean germination time of the viable seeds (approximately 3 days) in all locations was not significantly different from each other. There were no seeds of kenaf planted in August in Kishi, due to the cessation of rain at a critical time of capsule formation, while the seeds of the crop planted in August in Ikenne did not germinate during the quality test.

Table 4. Mean values of the location and planting date interaction of kenaf seed yield and quality.

Location	Planting date	Plant height (cm)	No. of capsules per plant	No. of seeds per capsule	Seed wt. per plant (g)	Total seed weight (g)	Seed yield/ha (kg)	SVI	Seed viability (%)	MGT (days)
Kishi	June	137.3	36	23	7.2	178.4	718.1	7.7	85	2.9
	July	161.9	34	20	0.2	6.9	22.3	4.0	66	3.0
	August	162.2	0	0	0	0	0	0	0	0
Ilora	June	99.7	27	22	16.1	332.3	1611.3	10.1	97	3.1
	July	129.9	47	23	7.3	250.3	729.6	5.7	73	3.1
	August	143.5	33	21	1.3	181.1	132.9	0.8	47	3.4
Orin-Ekiti	June	135.5	39	21	14.3	292.2	1431.6	8.0	88	3.1
	July	93.9	30	17	6.3	73.0	627.4	6.8	88	3.0
	August	86.6	13	6	1.3	13.1	129.2	1.3	48	3.2
Ikenne	June	83.5	22	18	3.0	169.1	296.5	8.3	88	3.4
	July	83.2	27	14	2.6	130.9	255.1	0.8	47	3.2
	August	71.8	13	10	0.7	10.5	69.1	0.0	0	0.0
Ibadan	June	107.2	45	26	11.8	591.7	1176.9	7.5	89	3.1
	July	88.6	21	20	4.6	147.1	459.5	5.2	74	3.3
	August	90.4	18	15	2.3	36.1	230.8	1.8	53	3.4

The relationship between the plant height and seed yield attributes of kenaf

The plant height had a highly significant correlation with the number of capsules per plant and the number of seeds per capsule, while it was only positively

correlated with seed weight per plant and seed yield per hectare but not significant (Table 6). All the seed yield attributes were positively and highly significantly correlated.

Table 5. Correlations of the plant height and seed yield attributes of kenaf.

	Plant height	Number of capsules/plant	Number of seeds/capsule	Seed weight/plant	Seed yield/hectare
Plant height	1	0.47**	0.23**	0.11	0.11
Number of capsules/plant		1	0.29**	0.31**	0.31**
Number of seeds/capsule			1	0.41**	0.41**
Seed weight/plant				1	1.00**
Seed yield/hectare					1

The profitability of kenaf seed production across southwestern Nigeria

The gross margin analysis of kenaf seed yield across the locations revealed that the total variable cost (TVC) recorded in Orin Ekiti for each planting time was the highest when compared to other locations. Also, the TVC recorded in the plantings done in June in all the locations except Ikenne was the highest, with Orin Ekiti recording the highest (₦705,650:00) TVC (Table 6). The lowest TVC (₦250,000) was observed in August plantings in Ikenne. The gross margin value of June planting was significantly higher in all the locations. The sums of ₦701,650, ₦1,736,400 ₦1,441.750, ₦184,750, ₦1,224,950 were obtained as gross margin values for June plantings in Kishi, Ilora, Orin-Ekiti, Ikenne and Ibadan, respectively. July plantings in some locations recorded low gross margins, while all plantings done in August returned negative gross margins regardless of the production station (Table 6). The varied cost of production across locations can be connected to the price fluctuations of inputs as well as accessibility and negotiation for labour input. High TVC recorded in June across locations was due to the scarcity of farm hands.

The month of June is the peak period for agricultural activities. However, the majority of the available labour was not easily accessible due to the engagement in personal farming operations, and the few available farm hands increased their charges in the cost of farming operations. This corroborates the findings of Aminu et al. (2020) that farm input use depends on the time and type of operational activities. The high cost of production in Orin-Ekiti was a result of purchases and the non-availability of inputs in the area. The transportation cost of inputs from the head office of these agencies to Orin-Ekiti often leads to the increased cost of the inputs.

Table 6. The gross margin analysis for kenaf seed yield across locations.

Location	Planting date	Total seed weight (g)	Seed yield/ha (kg)	Price/kg (#)	Revenue/ha	TVC	GM
Kishi	June	178.4	718.1	1,500	1,077,150.	375,500	701,650
	July	6.9	22.3	1,500	33,450	360,000	-326,550
	August	0	0		0	255,000	-255,000
Ilora	June	332.3	1611.3	1,500	2,416,950	680,550	1,736,400
	July	250.3	729.6	1,500	1,094,400	658,000	436,400
	August	181.1	132.9	1,500	199,350	550,000	-350,650
Orin-Ekiti	June	292.2	1431.6	1,500	2,147,400	705,650	1,441,750
	July	73.0	627.4	1,500	941,100	660,350	340,750
	August	13.1	129.2	1,500	193,800	650,000	-456,200
Ikenne	June	169.1	296.5	1,500	444,750	260,000	184,750
	July	130.9	255.1	1,500	382,650	265,500	117,150
	August	10.5	69.1	1,500	103,650	250,000	-146,350
Ibadan	June	591.7	1176.9	1,500	1,765,350	540,400	1,224,950
	July	147.1	459.5	1,500	689,250	520,650	168,600
	August	36.1	230.8	1,500	346,200	480,500	-134

TVC: Total variable cost; GM: Gross margin.

Conclusion

The study reveals that kenaf seed yield and quality are highly influenced by the production environment. The most appropriate month to plant kenaf for optimum seed yield of high quality and a profitable gross return on investment is June in southwestern Nigeria.

References

Adetumbi, J.A., Orimadegun, I.O, Akinyosoye, S.T., Akintayo, O.T., & Agbeleye O.A. (2019). Enhancing planting value of rice seed through priming with humic substance. *Journal of Experimental Agriculture International, 29* (6), 1-8.

Akinrotimi, C.A., & Okocha, P.I. (2018). Effects of planting year and genotypes on the seed yield of Kenaf (*Hibiscus cannabinus L.*). *Journal of Plant Sciences and Agricultural Research, 2* (2), 1-5.

Al-Mudaris, M.A. (1998). Notes on various parameters recording the speed of seed germination. *Journal of Agriculture in the Tropics and Subtropics, 99*, 141-154.

Aminu, F.O., Mohammed, H.A., & Iheagwan, C.I. (2020). Determinants of labour use among Ofada Rice Farmers in Ewekoro Local Government Area of Ogun State, Nigeria. *Agricultural Economics and Extension Research Studies (AGEERS)*, *8* (2), 11-20.

Amusat, A.S., & Ademola, A.O. (2014). Information needs of Kenaf farmers in Ogbomosho zone of Oyo State, Nigeria. *American Journal of Experimental Agriculture, 4* (12), 1625-1636.

Catao, H.C., Gommes, L.A.A., Guimaraes, R.M., Fonseca, P.H.F., Caixeta, F., & Galvao, G. (2018). Physiological and biochemical changes in lettuce seeds during storage at different temperatures. *Horticultura Brasileira, 36*, 118-125.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., & Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early Twenty-first century. *Philosophical Transactions of the Royal Society B, 365*, 2973-2989.

Huho, J.M., Ngaira, J.K.W., Ogindo, H.O., & Masayi, N. (2012). The changing rainfall pattern and the associated impacts on subsistence agriculture in Laikipia East District, Kenya. *Journal of Geography and Regional Planning, 5* (7), 198-206.

ISTA (2003). *International Rules for Seed Testing Association* (ISTA), Zurich, Switzerland.

Kyei-Mensah, C., Kyerematen, R., & Adu-Acheampong, S. (2019). Impact of rainfall variability on crop production within the Worobong ecological area of Fanteakwa district, Ghana. *Advances in Agriculture,* 2019, Article ID 7930127. https://doi.org/10.1155/2019/7930127

Lee, E.P., Han, Y.S., Lee, S.I. Cho, K.T., Park, J.H., & You, Y.H. (2017). Effect of nutrient and moisture on the growth and reproduction of *Epilobium hirsutum* L., an endangered plant. *Journal of Ecology Environment, 41*, 35. https://doi.org/10.1186/s41610-017-0054-z

LeMahieu, P.J., Oplinger, E.S., & Putnam, D.H. (2003). *Kenaf. In: Alternative Field* crops Manual.http://www.corn. agronomy.wisc.edu/FISC/Alternatives/Kenaf.htm

Mollah, A.F., Islam, M., Rahman, S., Tareq, Z., & Haque, S.M.A. (2015). Yield and cost of kenaf seed production as influenced by planting date and method. *International Journal of Sustainable Agricultural Technology, 11* (12), 1-6.

Muhamed, A., Bhardwaj, H., Hamama, A., & Webber, C. (1995). Chemical composition of Kenaf *(Hibiscus canabinus* L) seed oil. *Industrial Crops and Products, 4* (3), 157-165.

Murumkar, A.R., Arya, D.S., & Rahman, M.M. (2013). Seasonal and annual variations of rainfall pattern in the Jamuneswari Basin, Bangladesh. *In* Mu. Ramkumar (ed.), *On a Sustainable Future of the Earth's Natural Resources*. (pp 349–362). Springer Earth System Sciences.

Ogunniyan, D.J. (2016). Assessment of genetic divergence in kenaf (*Hibiscus cannabinus* L.) genotypes using agro-botanical characteristics and multivariate analysis. *SABRAO Journal of Breeding & Genetics, 48* (1), 61-71.

Ogunniyan, D.J., Adeniyan, O.N., Aluko, O.A., Olanipekun, S.O., & Anjorin, F.B. (2016). Seasonal performance and traits relationship of kenaf (*Hibiscus cannabinus* L.) cultivars grown in forest-savannah-transition agro-ecology. *Moor Journal of Agricultural Research, 17*, 37-50.

Olanipekun, S.O., & Togun, A.O. (2020). Effect of planting date on the growth, fibre and seed yield of Kenaf (*Hibiscus cannabinus L*) in Ibadan, South western Nigeria. *Journal of Applied Science and Environmental Management*, *24* (10), 1711-1714.

Olasoji, J.O., Aluko, O.A., Agbaje, G.O., Adeniyan, O.N., Kareem, K.O., & Olanipekun, S.O. (2014). Studies on seed yield potential of some selected kenaf (*Hibiscus cannabinus L.*) genotypes. *African Journal of Biotechnology, 13* (24), 2420-2424.

Received: September 1, 2021
Accepted: July 4, 2022

ODGOVARAJUĆE VREME SETVE ZA PROFITABILNU PROIZVODNJU KVALITETNOG SEMENA KENAFA (*HIBISCUS CANABINUS L.*) U JUGOZAPADNOJ NIGERIJI

Johnson A. Adetumbi*, Dotun J. Ogunniyan, Sikiru Ajijola, Ajoke Oyegbami i Olutayo N. Adeniyan

Institut za poljoprivredna istraživanja i obuku, Univerzitet Obafemi Awolowo, Ibadan, Država Ojo, Nigerija

R e z i m e

Nizak prinos semena postignut u proizvodnji kenafa u različitim agroekološkim uslovima u jugozapadnoj Nigeriji delimično se pripisuje uticaju klimatskih promena. Stoga je sproveden eksperiment kako bi se utvrdio odgovor kenafa na preovlađujuće vremenske uslove i odredilo najprikladnije vreme setve za postizanje optimalnog prinosa semena prihvatljivog kvaliteta koji će biti isplativ u vlažnim uslovima Nigerije. Istraživanje je sprovedeno u pet istraživačkih stanica (Ibadan, Ilora, Ikene, Orin Ekiti i Kisi) Instituta za poljoprivredna istraživanja i obuku u Ibadanu (Nigerija) u vegetacionim sezonama 2018. i 2019. godine (jun–avgust). Posejana su semena kenafa pet sorti (Cuba108, Ifeken DI 400, Ifeken100, Ifeken 400 i Tianung-2) u mesečnom intervalu od juna do avgusta svake godine u randomiziranom kompletnom blok dizajnu sa tri ponavljanja. Žetva, vršidba i čišćenje su ručno obavljeni, nakon čega su uzorci čistog semena analizirani u pogledu kvaliteta semena. Dobijeni su podaci o visini biljke prilikom žetve, osobinama vezanim za prinos semena i parametrima koji se odnose na kvalitet semena. Takođe je sprovedena analiza profitabilnosti kako bi se procenili troškovi i prihodi od proizvodnje na različitim lokacijama. Proizvodni uslovi imaju veliki uticaj na prinos i kvalitet semena kenafa. Zaključeno je da će setva kenafa sredinom juna u jugozapadnoj Nigeriji dati optimalan prinos semena visokog kvaliteta uz isplativ bruto povraćaj od ulaganja.

Ključne reči: kenaf, datum setve, kvalitetno seme, vlažna agroekologija.

Primljeno: 1. septembra 2021.
Odobreno: 4. jula 2022.

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

Journal of Agricultural Sciences (Belgrade)
Vol. 67, No. 3, 2022
Pages 269-283

https://doi.org/10.2298/JAS2203269J
UDC: 633.31:632.752.1(497.11)
Original scientific paper

EFFECTS OF TEMPERATURE ON *ACYRTHOSIPHON PISUM* AND *THERIOAPHIS TRIFOLII* (HEMIPTERA: APHIDIDAE) ABUNDANCE IN ALFALFA CROPS: A CASE STUDY IN NORTHERN SERBIA

Ivana S. Jovičić[1*], Mirjam P. Vujadinović[2], Ana J. Vuković[2], Anđa B. Radonjić[3] and Olivera T. Petrović-Obradović[3]

[1]Institute of Pesticides and Environmental Protection,
Banatska 31b, 11080 Belgrade-Zemun, Serbia
[2]University of Belgrade-Faculty of Agriculture,
Institute of Horticulture, Nemanjina 6, 11080 Belgrade-Zemun, Serbia
[3]University of Belgrade-Faculty of Agriculture,
Institute of Phytomedicine, Nemanjina 6, 11080 Belgrade-Zemun, Serbia

Abstract: Populations of the most abundant alfalfa aphids, *Acyrthosiphon pisum* and *Therioaphis trifolii*, have periodic fluctuations, and many factors affect their dynamics. In the present study, we examined the impact of daily air temperatures on the abundance of two alfalfa aphids in field conditions. The numbers of these two aphids on alfalfa were documented at two locations in a representative alfalfa growing area in Serbia during a three-year field study. Based on the records of aphid abundance and daily air temperatures during the whole study, it was found that a correlation between the sum of optimal daily air temperatures for aphid development, the sum of maximum daily air temperatures and the number of recorded aphid peaks was significant and can therefore be considered for the detection of suitable temperature conditions to increase aphid abundance. The study shows that the highest correlations were between a high density of *A. pisum* and the sum of optimal daily air temperatures for its development (Ck=0.569) and between a high density of *T. trifolii* and the sum of maximum daily air temperatures (Ck=0.595). The length of time required for the growth of populations of the two alfalfa aphids differed: 30 days for *A. pisum* and 5 days for *T. trifolii*. The association of temperature data to alfalfa aphid abundance enables a projection of their population behavior in changed future climate conditions. This study suggests increased population sizes of *T. trifolii* and decreased population sizes of *A. pisum* on alfalfa under the warmer conditions that are expected to prevail in the future.

Key words: alfalfa aphids, abundance, *Medicago sativa*, temperature conditions, climatic changes.

[*]Corresponding author: e-mail: ivana.jovicic@pesting.org.rs

Introduction

Over the past decades, climate change has accelerated worldwide, bringing increases in temperature, changes in precipitation regimes and more frequent and severe extreme events, such as droughts and heatwaves. Changes in climate conditions and their variability are among the most important threats to agriculture and biodiversity. Plants are more frequently exposed to heat and/or water stress, pests and diseases, which significantly influence the quality and quantity of yields and, consequently, food availability (IPCC, 2014).

Insect population dynamics depend on many factors, such as host-plant quality, biological forces (predators and parasitoids) and, in particular, climate conditions (Kindlman and Dixon, 2010). Insect herbivores and the plants involved in their development are dependent on many climatic factors: temperature, solar radiation, precipitation and relative humidity. Current knowledge suggests that climate change through temperature increases, changes in precipitation regime and more frequent extreme events can alter an insect's development (Bale et al., 2002; Bale and Hayward, 2010; Colinet et al., 2015; Castex et al., 2018). Several studies have shown that temperature directly affects insect population abundance, development, survival, the number of generations, distribution and invasion by exotic insect pests (Bale, 2002; Satar et al., 2005). Since insects are poikilothermic organisms, their body temperature depends on the external environment and is highly sensitive to temperature variability (Bale and Hayward, 2010).

Of all environmental factors that influence aphid abundance, the temperature is of major importance. Aphids can develop over a limited range of temperatures (Dixon et al., 2009). Because of their short generation time and high reproductive capacity, they have the potential to respond rapidly to temperature increases (Harrington et al., 2007).

Three aphid species develop on alfalfa in Serbia: the pea aphid *Acyrthosiphon pisum* (Harris), the cowpea aphid *Aphis craccivora* Koch and the spotted alfalfa aphid *Therioaphis trifolii* (Monell) (Tomanović et al., 1996; Petrović-Obradović and Tomanović, 2005; Jovičić et al., 2016). Alfalfa aphids can reduce crop yields directly through their feeding (Lykouressis and Polatsidis, 1990; Pons et al., 2009; Ryalls et al., 2013; Jovičić et al., 2016) and indirectly through the transmission of the plant-pathogenic viruses such as *Alfalfa mosaic virus* (AMV) and *Cucumber mosaic virus* (CMV) (Bol, 2010; García-Arenal and Palukaitis, 2010). Recent research into aphid population dynamics on alfalfa in Serbia has shown that *T. trifolii* is the most abundant species, followed by *A. pisum* (Jovičić et al., 2017). Earlier studies found that three decades ago, in the Pannonian area, *A. pisum* was more abundant than the two other species (Tomanović et al., 1996). *Aphis craccivora* is a comparatively minor pest of alfalfa and rarely occurs in high numbers on this plant (Berberet et al., 2009; Ryalls et al., 2013; Jovičić et al., 2016).

Over the last 50 years, the mean annual temperature in Serbia has increased with a trend of 0.36°C per 10 years. Since the 1980s, the observed warming has accelerated to a trend of 0.6°C per 10 years. The average mean annual temperature in the period 2008–2017 was about 1.5°C higher in comparison to the period 1961–1990, while the mean temperature of summer months (June, July, August) increased even more, by over 2.5°C compared to the same reference period (Djurdjevic et al., 2018).

Considering the observed temperature increases, especially pronounced during the vegetation season, and the prevalence of *T. trifolii* over *A. pisum* on alfalfa observed in Serbia in the last decade, the aim of this study was to explore the impact of air temperature on the abundance of these two alfalfa aphids in field conditions.

Material and Methods

Aphid sampling

The study was conducted in two alfalfa fields in Serbia located in Progar (the Srem region) and Ovča (South Banat) in a representative alfalfa production area. The plots were approximately 1 ha in Ovča and 0.5 ha in Progar. Aphids were monitored in order to determine the abundance of *A. pisum* and *T. trifolii* during the growing season (from April to October) in 2011–2012 in Progar and 2011–2013 in Ovča. Aphids were collected directly from plants and placed in plastic tubes containing 70% ethanol. Samples were taken every 10 days from both locations. The identification of aphids was carried out based on identification keys (Blackman and Eastop, 2000) using a stereomicroscope. The total number of *A. pisum* and *T. trifolii* per 100 alfalfa stems was counted on each sampling date.

Weather conditions

The analysis of meteorological conditions in the two alfalfa fields in Srem and Southern Banat was performed using data recorded at two nearby official meteorological stations, Surčin (near Progar) and Banatski Karlovac (near Ovča), run by the Hydrometeorological Service of the Republic of Serbia. Mean monthly temperatures in the years of the case study were compared to climatological values of the reference period 1986–2013, while daily maximum and minimum air temperatures were used in degree-day calculations.

Statistical analysis

A degree-day method was used to determine the length of time required for the growth of populations of the two alfalfa aphids. Temperature sums were

calculated for a period from 1 to 45 days, with steps of 5 days, before the aphids reached their peaks: the total number of *A. pisum* or *T. trifolii* per 100 alfalfa stems was 100 or more.

The effect of temperature on *A. pisum* was calculated as a correlation between the sum of optimal daily air temperatures for its development, i.e. the accumulated degrees-day15–25ºC, the sum of maximum air temperatures and the number of recorded peaks. For *T. trifolii*, the correlation between the sum of optimal daily air temperatures for its development, i.e. the accumulated degrees-day 20–30ºC, the sum of maximum air temperatures and the number of peaks recorded for the sample was calculated. Data on the thermal requirements for the development of two alfalfa aphids were obtained from the literature (Bieri et al., 1983; Berberet et al., 1983; Lykouressis and Polatsidis, 1990; Lamb, 1992; Liu et al., 2012). The correlation coefficient C_k (where 1 is a total positive correlation, 0 is no correlation, and -1 is a total negative correlation) was calculated using a self-developed FORTRAN code.

The correlation coefficient was calculated using the following formula:

$$C_k = \frac{\sum_{i=1}^{n}[(x_{ki}-\overline{x_k})(y_i-\bar{y})]}{\sqrt{\sum_{i=1}^{n}[(x_{ki}-\overline{x_k})^2(y_i-\bar{y})^2]}} \quad (1)$$

n – the number of samples;

x_k – the sum of temperatures $t\ x_k = \sum_{j=1}^{k} t_j$, for period $k=1,5,..45$ days before the aphid peak;

y – the number of aphids at their peak.

Results and Discussion

Field studies

The maximum population densities of *A. pisum* on alfalfa were recorded in spring at both locations in all years, and in the autumn of 2011 at Ovča. The maximum population densities of *T. trifolii* at both locations were recorded during the summer (2011–2013).

The peaks of *A. pisum* (100 individuals per 100 alfalfa stems or more) were recorded in mid-May at Progar during 2011–2012, and at the end of April (2011), in May (2011–2013), mid-June (2013) and mid-October (2011) at Ovča (Table 1).

The peaks of *T. trifolii* were recorded at the end of August and at the beginning of September (2012) at Progar, and at the end of July and August (2011–2013) and at the beginning of September (2012) at Ovča (Table 1).

Table 1. Dates of recorded peaks and the number of recorded individuals of *A. pisum* and *T. trifolii* per 100 alfalfa stems at the Progar locality in 2011–2012 and at the Ovča locality in 2011–2013.

Aphid *A. pisum*				*T. trifolii*			
Locations	Progar	Ovča		Progar		Ovča	
Dates of sampling and the number of recorded aphid individuals per 100 alfalfa stems (in peaks)							
2011							
12 May	104	30 April	208	/		22 July	164
		10 May	222				
		20 May	232				
		19 October	171				
2012							
19 May	114	18 May	235	18 August	338	24 July	114
				7 September	106	3 August	369
				18 September	1123	24 August	537
						3 September	164
2013							
	/	10 May	227	/		29 July	131
		17 June	108			19 August	179
						29 August	129

Temperature conditions

Based on the data from the Serbian Hydrometeorological Service (weather stations Banatski Karlovac and Surčin), the mean monthly air temperatures recorded for the three-year study period in Ovča and the two-year study period in Progar were compared to the 1986–2013 reference period (Figures 1 and 2). The mean monthly air temperatures recorded for the study period deviated from the climatological normal, particularly in 2012.

Temperatures at both locations in 2011 were within the climatological normal values, except in September, when the mean monthly air temperatures were above the long-term average.

The year of 2012 was one of the hottest years on record since the start of meteorological measurements in Serbia. The summer was especially hot, with extreme heat and drought conditions prevailing for months. In July of 2012, the mean monthly air temperature ranged from 24.6ºC in Ovča up to 26.5ºC in Progar, surpassing the maximum mean air temperatures recorded since 1986. At the same time, February of 2012 was the coldest month recorded in the study, with mean monthly air temperatures of -4ºC in Progar and -5.1ºC in Ovča. The mean monthly air temperatures at the Ovča site in 2013 were within the long-term normal values.

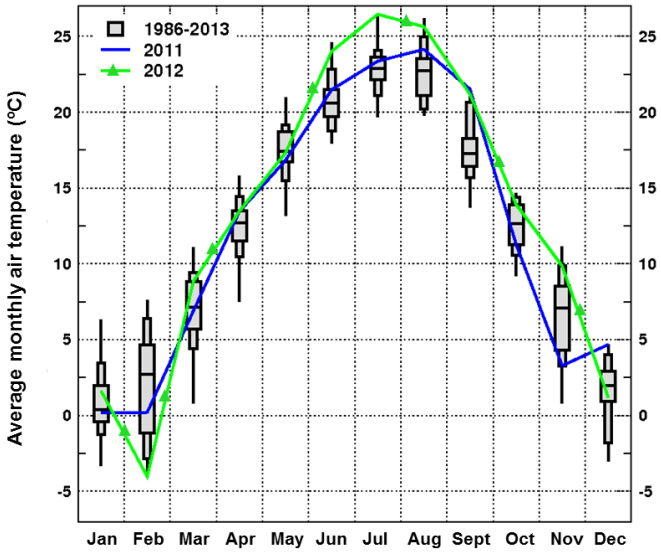

Figure 1. Average monthly air temperatures (ºC) in the period 1986–2013 and mean monthly air temperatures during the two-year study (2011 and 2012) at the Progar locality (Weather station Surčin).

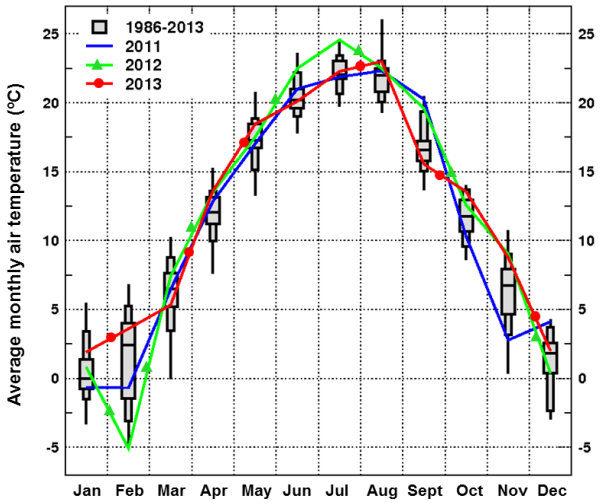

Figure 2. Average monthly air temperatures (ºC) in the period 1986–2013 and mean monthly air temperatures during the three-year study (2011, 2012 and 2013) at the Ovča locality (Weather station Banatski Karlovac).

Temperature effects on alfalfa aphids

Climate change is happening, and there is a need for a constant monitoring of its impact on pests such as aphids. Climate conditions, especially air temperature, have an effect on aphid population dynamics, and it is clear that climatic changes such as global warming are very likely to strongly affect their pest status (Harrington et al., 2007; Petrović-Obradović et al., 2018). Extreme air temperatures may affect insect development positively or negatively (Castex et al., 2018).

Aphids are the most destructive insect pests of alfalfa, causing production losses of 25% worldwide (He and Zhang, 2006). Heavy infestations of *A. pisum* and *T. trifolii* were reported in the main alfalfa growing regions in Serbia. The most abundant aphid on alfalfa, *T. trifolii*, is adapted to warmer temperatures. The second one, *A. pisum*, is adapted to cooler temperatures. Previously recorded results of Tomanović et al. (1996) clearly showed that, three decades ago, *A. pisum* was dominant in comparison to *T. trifolii* on alfalfa in Serbia. In the past 20–30 years, the warmer climate and changes in the rainfall regime have significantly influenced the previously established occurrences of *A. pisum* and *T. trifolii*.

Temperature effects on the abundance of *A. pisum*

In this study, a correlation was found between the maximum population density (peaks) of *A. pisum* and the sum of optimal and maximum daily air temperatures.

In the series of calculated correlations for different periods, the highest correlation (Ck=0.569) was observed between the sum of the optimal daily air temperatures in the range of 15–25ºC and the maximum population density of *A. pisum*, 30 days before this aphid reached its peaks (Table 2, Figure 3). The next high correlation (*Ck*=0.542) was noted between the sum of maximum daily air temperatures and the maximum population density of *A. pisum*, also 30 days before it reached its peaks (Table 2, Figure 3).

Table 2. Correlations between the sums of air temperatures for every five days and the maximum population density of *A. pisum*.

	The number of days before the peak								
	5	10	15	20	25	30	35	40	45
Sum Topt	-0.182	0.337	0.482	0.470	0.541	0.569	0.480	0.386	0.318
Sum Tx	-0.130	0.213	0.406	0.459	0.514	0.542	0.460	0.293	0.219

(Sum Topt – the sum of optimal daily air temperatures in the range of 15–25ºC; Sum Tx – the sum of maximum daily temperatures).

A high variation between correlation values in the series of calculated correlations was found. A negative correlation coefficient between the sums of optimal and maximum daily air temperatures and maximum *A. pisum* population density was found five days before its peaks. The correlation coefficient values gradually increased in the next steps (10 to 30 days), and in the 30- to 45-day periods, the values gradually decreased (Table 2).

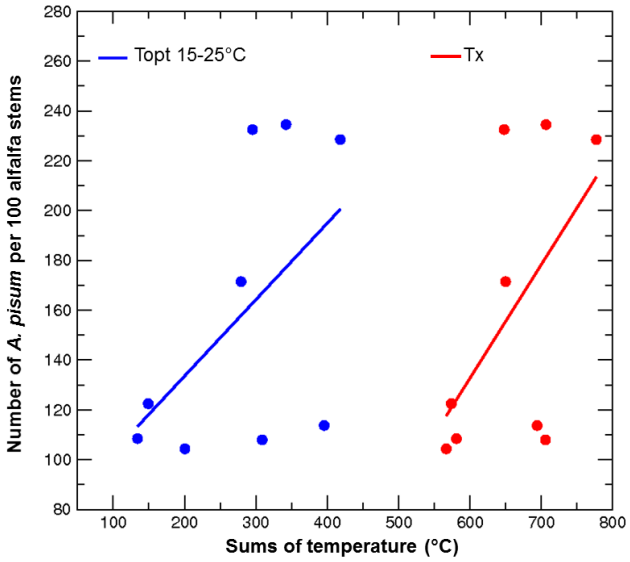

Figure 3. Correlations between the abundance of *A. pisum* and sums of optimal daily air temperatures in the range of 15–25ºC (Topt) and sums of maximum daily air temperatures (Tx) 30 days before its peak.

Aphid populations continuously adapt to alterations in their environments, such as increases in air temperature. Compared to other insects, aphids have a low developmental temperature threshold (around 4°C), developmental optimum (around 25°C) and a short generation time (Harrington et al., 2007). Temperatures primarily affect the abundance of *A. pisum*. The optimum temperature range for its population growth is 15–25°C (Berberet et al., 1983; Lamb et al., 1987; Lamb, 1992). The results of *A. pisum* population fluctuations in Serbia clearly showed the existence of two periods, spring and autumn, when development may occur under the prevailing air temperatures. The maximum population density of *A. pisum* (100 individuals per 100 alfalfa stems or more) has been recorded at the end of April, in May and mid-June (2011–2013) at both locations and in mid-October (2011) in Ovča. The mean monthly air temperature in this period ranged between 15°C and 20°C. Correlations between the sums of the optimal daily air temperatures, maximum daily temperatures and the maximum population density of *A. pisum* on

alfalfa were Ck=0.569 (Sum Topt) and Ck=0.542 (Sum Tmax). The air temperatures during spring and autumn have large oscillations, and cooler conditions cause slower heat accumulation. Consequently, the length of time required for the growth of a population of *A. pisum* was 30 days. During this period, aphids accumulated temperatures for their development.

Cold-adapted species such as *A. pisum* are adversely affected by warming. The low population density of this species during the summer months is connected with the adverse effects of high temperatures. The mean monthly air temperature in the summer months (2011–2013) was around 25°C. This temperature is the upper limit in the optimum temperature range for *A. pisum* population growth. Thus, maximum daily air temperatures of 35°C or higher during the summer may be detrimental to its development. The extremely high summer temperatures in 2012 at both locations limited *A. pisum* development up to the end of the growing season. Based on these results, we assume that higher air temperatures have a negative influence on the survival and reproduction of *A. pisum* populations. Similar effects of temperature on aphids were recorded in other studies. High temperatures over 30°C were detrimental to the survival of *Metopolophium dirhodum* (Walker) on cereals in central Europe (Ma et al., 2004). Satar et al. (2005) reported that the optimal temperature range for the population growth of *Brevicoryne brassicae* (L.) on white cabbage was about 25°C, while temperatures of 30–35ºC were lethal to the early larval stages. Furthermore, the effects of temperature on insect herbivores can be direct through impacts on their physiology and behavior, or indirect through impacts on their host plant (Bale et al., 2002). Barton and Ives (2014) have shown that drought in alfalfa fields and the deterioration of plant quality lowered the population growth rate of *A. pisum.* The deterioration of alfalfa plant quality recorded in the summer of 2012 at both locations was also detrimental to *A. pisum* development.

Temperature effects on the abundance of *T. trifolii*

A correlation was found between the maximum population density (peaks) of *T. trifolii* and the sums of optimal daily air and maximum daily temperatures.

In the series of calculated correlations for different periods, the highest correlation (Ck=0.595) was found between the sum of maximum daily air temperatures and the maximum population density of *T. trifolii*, 5 days before it reached its peaks (Table 3, Figure 4). The next high correlation (Ck=0.546) was observed between the sum of optimal daily air temperatures and the maximum population density of *T. trifolii*, also 5 days before it reached its peaks (Table 3, Figure 4).

The correlation coefficient between the sum of optimal and maximum daily temperatures and the maximum population density of *T. trifolii* for the remaining period (10 to 45 days) had low positive or negative values (Table 3).

Table 3. Correlations between the sums of air temperatures for every five days and the maximum population density of *T. trifolii*.

	The number of days before the peak								
	5	10	15	20	25	30	35	40	45
Sum Topt	0.546	0.311	-0.270	-0.122	0.062	0.255	0.320	0.309	0.283
Sum Tx	0.595	0.193	-0.285	-0.311	-0.143	0.049	0.036	-0.016	0.183

(Sum Topt – the sum of optimal daily air temperatures in the range of 20–30ºC; Sum Tx – the sum of maximum daily temperatures)

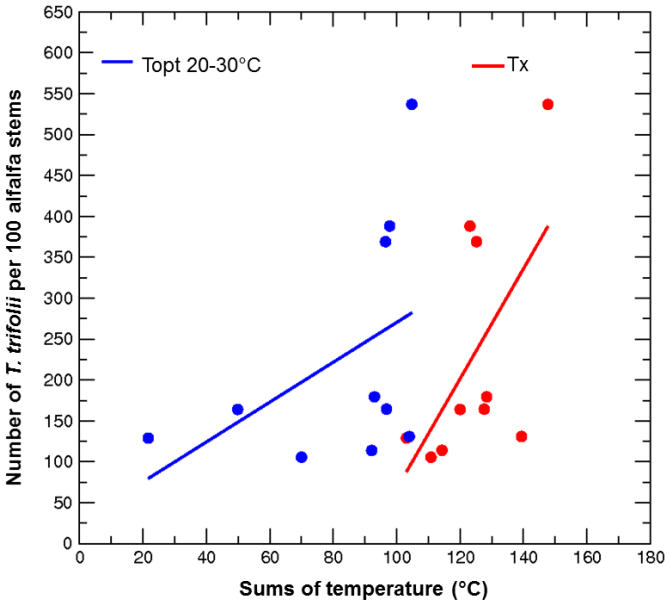

Figure 4. Correlations between the abundance of *T. trifolii* and sums of optimal daily air temperatures in the range of 20–30ºC and sums of maximum daily air temperatures 5 days before its peak.

The prevalence of *T. trifolii* on alfalfa in this study might be related to climate change. High temperatures and dry weather are optimal for increasing the abundance of *T. trifolii*. The fecundity of this species is highest at 25°C (Liu et al., 2012). The maximum population density of *T. trifolii* on alfalfa was recorded in the period July–September (2011–2013) at both locations. The mean monthly air

temperature in this period ranged from 22°C to 26°C. In July 2012, at Progar and Ovča, extremely high mean daily air temperatures (about 30°C) were recorded. This temperature is the upper limit in the optimum temperature range for *T. trifolii* population growth. However, the short-term exposure of *T. trifolii* to high temperatures had a positive impact on its development. The highest number of peaks at both locations was recorded in the summer of 2012, which was one of the hottest summers since the start of meteorological measurements in Serbia (Djurdjevic et al., 2018).

The high density of this aphid on alfalfa was positively correlated with the sums of maximum daily air temperatures (Ck=0.595) and optimal daily air temperatures (Ck=0.546). The length of time required for the population growth of *T. trifolii* was 5 days. Higher temperatures tend to increase the speed of multivoltine insects' life cycle (Bale, 2002). Castex et al. (2018) have shown that warmer conditions cause faster and earlier heat accumulation, accelerating development rates and increasing the number of generations an insect can achieve in one year. Several studies showed that some aphids become more abundant with elevated temperatures. Davis et al. (2006) showed that an increase in temperature of 2.5–3.5°C correlated positively with an increase in *Myzus persicae* (Sulzer) abundance. The fecundity of *Rhopalosiphum maidis* (Fitch) on barley was higher under elevated temperatures (Xie et al., 2014). Furthermore, the higher production of winged forms that leads to increased aphid migration and a spread of plant viruses was observed (Xie et al., 2014). Also, in hot summers, *T. trifolii* has a high production of winged forms (Jovičić et al., 2017).

Studies on climate change in Europe point to an increase in temperature, changes in precipitation regimes and more frequent extremes (e.g. heat waves), particularly in the southeastern part of the continent (IPCC, 2014). According to the European Environment Agency (EEA, 2017), Serbia ranks among the countries most susceptible to the adverse effects of this change. Vuković et al. (2018) show that, by the end of the 21st century, the mean summer temperature in Serbia could be 4.5°C higher in comparison to the reference period 1986–2005, with an earlier onset and later end of the vegetation period and more frequent and intensive heat waves and drought events. In addition to other newly detected pests in Serbia, whose occurrences are confirmed as a consequence of climate change impacts (Stričević et al., 2020), the abundance of *T. trifolii* and *A. pisum* on alfalfa can also serve as climate change impact indicators. We suggest including these two alfalfa aphids in the list of proposed indicators, which are planned for continual monitoring with the purpose of enhancing adaptation capacities in agricultural production.

Conclusion

According to our results, *T. trifolii* populations on alfalfa in Serbia are well adapted to high air temperatures between 30 and 35°C. However, the high air temperature has a detrimental role in the population development of *A. pisum*. The results of this study could be used as a starting point in defining short- and long-term prognoses of aphid abundance on alfalfa in the following years, as well as enabling the timely preparations for a significant climate shift by the end of the century. Clearly, it is difficult to predict the effect of global warming on aphid populations. The direct effects of temperature on aphids need to be analyzed in a wider context, and attention should be paid to the effects interacting with other climatic factors (primarily precipitation), natural aphid enemies (predators and parasitoids) and host-plant conditions.

Acknowledgments

This research was supported by grants nos. 451-03-9/2021-14/200214 and 451-03-9/2021-14/200116 of the Ministry of Education, Science and Technological Development, Republic of Serbia.

References

Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Butterfield, J.E.L., Buse, A., Coulson, J.C., Farrar, J., Good, J.E.G., Harrington, R., Hartley, s., Jones, T.H., Lindroth, R.L., Press, M.C., Symrnioudis, I., Watt, A.D., Whittaker, J.B. (2002). Herbivory in global climate change research: direct effects of rising temperatures on insect herbivores. *Global Change Biology, 8*, 1-16.

Bale, J.S., & Hayward, S.A.L. (2010). Insect overwintering in a changing climate. *The Journal of Experimental Biology, 213*, 980-994.

Barton, B.T., & Ives, A.R. (2014). Species interactions and a chain of indirect effects driven by reduced precipitation. *Ecology, 95*, 486-494.

Berberet, R.C., Arnold, D.C., & Soteres, K.M. (1983). Geographical occurrence of *Acyrthosiphon kondoi* Shinji in Oklahoma and its seasonal incidence in relation to *Acyrthosiphon pisum* (Harris), and *Therioaphis maculata* (Buckton) (Homoptera: Aphididae). *Journal of economic entomology*, *76* (5), 1064-1068.

Berberet, R.C., Giles, K.L., Zarrabi, A.A., & Payton, M.E. (2009). Development, reproduction, and within-plant infestation patterns of *Aphis craccivora* (Homoptera: Aphididae) on alfalfa. *Environmental entomology, 38* (6), 1765-1771.

Bieri, M., Baumgartner, J., Bianchi, G., Delucchi, V., & Arx, R.V. (1983). Development and fecundity of pea aphid (*Acyrthosiphon pisum* Harris) as affected by constant temperatures and by pea varieties. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 56 (1/2), 163-171.

Bol, J.F. (2010). Alfalfa mosaic virus. In M. H. V., Van Regenmortel, & B. W. J., Mahy (Eds.), *Desk Encyclopedia of Plant and Fungal Virology* (pp. 85-91). Elsevier and Academic Press, Oxford, UK.

Blackman, R.L., & Eastop, V.F. (2000). *Aphids on the World's Crops. An Identification and Information Guide, 2nd ed*. Natural History Museum, London, UK.

Castex, V., Beniston, M., Calanca, P., Fleury, D., & Moreau, J. (2018). Pest management under climate change: The importance of understanding tritrophic relations. *Science of the Total Environment, 616-617*, 397-407.

Colinet, H., Sinclair, B.J., Vernon, P., & Renault, D. (2015). Insects in Fluctuating Thermal Environments. *Annual Review Entomology, 60*, 123-140.

Davis, J.A., Radcliffe, E.B., & Ragsdale, D.W. (2006). Effects of high and fluctuating temperatures on *Myzus persicae* (Hemiptera: Aphididae). *Environtal Entomology, 35* (6), 1461-1468.

Dixon, A.F.G., Honek, A., Keil, P., Kotela, M.A.A., Sizling, A.L., & Jarosik, V. (2009). Relationship between the minimum and maximum temperature thresholds for development in insects. *Functional Ecology, 23*, 257-264.

Djurdjevic, V., Vukovic A., & Vujadinovic Mandic, M. (2018). Observed climate change in Serbia and climate change projections based on different emission scenarios (in Serbian), United Nations Development Program.

EEA - European Environment Agency (2017). https://www.eea.europa.eu/data-and-maps/figures/key-past-and-projected-impacts-and-effects-on-sectors-for-themainbiogeographic-regions-of-europe-3. (Retrieved 28 November 2018).

García-Arenal, F., & Palukaitis, P. (2010). Cucumber mosaic virus. In M. H. V., Van Regenmortel, & B. W. J., Mahy (Eds.), *Desk Encyclopedia of Plant and Fungal Virology* (pp. 171-176). Elsevier and Academic Press, Oxford, UK.

Harrington, R., Clark, S.J., Welham, S.J., Verrier, P.J., Denholm, C.H., Hullé, M., Maurice, D., Rounsevell, M.D.A., Cocu, N., & European Union Examine Consortium (2007). Environmental change and the phenology of European aphids. *Global Change Biology, 13*, 1550-1564.

He, C.G., & Zhang, X.G. (2006). Field evaluation of lucerne (*Medicago sativa* L.) for resistance to aphids in northern China. *Australian Journal of Agricultural Research, 57*, 471–475.

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

Jovičić, I., Radonjić, A., & Petrović-Obradović, O. (2016). Alfalfa aphids (Hemiptera: Aphididae) and coccinellid predators in Serbia: seasonal abundance. *Acta zoologica Bulgarica*, *68* (4), 581-587.

Jovičić, I., Radonjić, A., & Petrović-Obradović, O. (2017). Spotted alfalfa aphid, *Therioaphis trifolii* (Monell) (Hemiptera: Aphididae): Pest on alfalfa in Serbia. *Biljni lekar 45* (4), 384-390.

Lamb, R.J, MacKay, P.A., & Gerber, G.H. (1987). Are development and growth of pea aphids, *Acyrthosiphon pisum*, in North America adapted to local temperatures? *Oecologia, 72*, 170-177.

Lamb, R.J. (1992). Developmental Rate of *Acyrthosiphon pisum* (Homoptera: Aphididae) at Low Temperatures: Implications for Estimating Rate Parameters for Insects. *Environmental Entomology, 21* (1), 10-19.

Liu, C.Z., Du, J.L., Zhang, T.W., Qian, X.J., & Chen, Y.W. (2012). Effects of temperature on population parameters of *Therioaphis trifolii* (Monell) (Homoptera: Aphididae). *Ying yong sheng tai xue bao 23* (7), 1927.

Lykouressis, D.P., & Polatsidis C.P. (1990). Seasonal abundance of *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) and *Therioaphis trifolii* (Monell) (Homoptera: Callaphididae) on lucerne in central Greece. *Entomologia Hellenica*, *8*, 41-46.

Kindlmann, P., Dixon, A.F.G., & Michaud, J.P. (2010). *Aphid Biodiversity under Environmental Change, Patters and Processes*. 1st ed. Springer.

Ma, C.S., Hau, B., & Poehling, H. (2004). Effects of pattern and timing of high temperature exposure on reproduction of the rose grain aphid *Metopolophium dirhodum*. *Entomologia Experimentalis et Applicata, 110*, 1-65.

Satar, S., Kersting, U., & Ulusoy, M.R. (2005). Temperature Dependent Life History Traits of *Brevicoryne brassicae* (L.) (Hom., Aphididae) on White Cabbage. *Turkish Journal of Agriculture and Forestry*, *29*, 341-346.

Petrović-Obradović, O., & Tomanović, Ž. (2005). Aphids: Pests of alfalfa and clover. *Biljni lekar, 33* (5), 534-538.

Petrović-Obradović, O., Radonjić, A., Jovičić, I., Petrović, A., Kocić, K., & Tomanović, Ž. (2018). Alien species of aphids (Hemiptera: Aphididae) found in Serbia, new to the Balkan Peninsula. *Phytoparasitica*, *46* (5), 653-660.

Pons, X., Lumbierres, B., & Albajes, R. (2009). Heteropterans as aphid predators in inter-mountain alfalfa. *European Journal of Entomology, 106* (3), 369.

Ryalls, J.M., Riegler, M., Moore, B.D., & Johnson, S.N. (2013). Biology and trophic interactions of lucerne aphids. *Agricultural and Forest Entomology, 15* (4), 335-350.

Stričević, R., Srdjević, Z., Lipovac, A., Prodanović, S., Petrović-Obradović, O., Ćosić, M., & Djurović, N. (2020). Synergy of experts' and farmers' responses in climate-change adaptation planning in Serbia. *Ecological Indicators, 116*, 106481.

Tomanović, Ž., Brajković, M., Krunić, M., & Stanisavljević, Lj. (1996). Seasonal dynamics, parasitization and colour polymorphism of the pea aphid, *Acyrthosiphon pisum* (Harris) (Aphididae: Homoptera) on alfalfa in the South part of the Pannonian area. *Tiscia, 30*, 45-48.

Vuković, A.J., Vujadinović, M.P., Rendulić, S.M., Đurđević, V.S., Ruml, M.M., Babić, V.P., & Popović, D.P. (2018). Global warming impact on climate change in Serbia for the period 1961-2100. *Thermal Science*, *22* (6 Part A), 2267-2280.

Xie, H., Zhao, L., Wang, W., Wang, Z., Ni, X., Cai, W., & He, K. (2014). Changes in Life History Parameters of *Rhopalosiphum maidis* (Homoptera: Aphididae) under Four Different Elevated Temperature and CO2 Combinations. *Journal of Economic Entomology, 107* (4), 1411-1418.

Received: January 26, 2022
Accepted: June 8, 2022

UTICAJ TEMPERATURE NA BROJNOST *ACIRTHOSIPHON PISUM* I *THERIOAPHIS TRIFOLII* (HEMIPTERA: APHIDIDAE) U USEVIMA LUCERKE: STUDIJA SLUČAJA NA SEVERU SRBIJE

Ivana S. Jovičić[1*], Mirjam P. Vujadinović[2], Ana J. Vuković[2], Anđa B. Radonjić[3] i Olivera T. Petrović-Obradović[3]

[1]Institut za pesticide i zaštitu životne sredine,
Banatska 31b, 11080 Beograd - Zemun, Srbija
[2]Univerzitet u Beogradu – Poljoprivredni fakultet,
Institut za hortikulturu, Nemanjina 6, 11080 Beograd - Zemun, Srbija
[3]Univerzitet u Beogradu – Poljoprivredni fakultet,
Institut za fitomedicinu, Nemanjina 6, 11080 Beograd - Zemun, Srbija

R e z i m e

Na populacionu dinamiku dve najbrojnije vrste biljnih vaši lucerke, *Acyrthosiphon pisum* i *Therioaphis trifolii*, utiču brojni faktori. Istraživanje uticaja dnevnih temperatura vazduha na populacionu dinamiku biljnih vaši lucerke sprovedeno je u poljskim uslovima. Brojnost biljnih vaši je praćena tokom tri godine, na dva lokaliteta, u najznačajnijim proizvodnim regionima lucerke u Srbiji. Na osnovu podataka o brojnosti biljnih vaši na lucerki i vrednosti dnevnih temperatura vazduha tokom istraživanja, utvrđena je korelacija između suma optimalnih dnevnih temperatura za razvoj biljnih vaši, suma maksimalnih dnevnih temperatura vazduha i maksimuma brojnosti dve vrste biljnih vaši. Najviše vrednosti koeficijenta korelacije (Ck) bile su između maksimuma brojnosti *A. pisum* i sume optimalnih dnevnih temperatura za njen razvoj (Ck=0,569), kao i između maksimuma brojnosti *T. trifolii* i sume maksimalnih dnevnih temperatura vazduha (Ck=0,595). Za porast brojnosti populacije *A. pisum* neophodno je da odgovarajući temperaturni uslovi budu ispunjeni u trajanju od 30 dana, dok je za porast brojnosti populacije *T. trifolii* neophodno 5 dana. Nalaženje veze između temperaturnih uslova i brojnosti biljnih vaši lucerke omogućava nam predviđanje njihovog ponašanja i brojnosti u izmenjenim klimatskim uslovima koji nas očekuju u budućnosti. Ova istraživanja ukazuju da se u budućnosti, usled globalnog zagrevanja, očekuje porast brojnosti *T. trifolii* i smanjenje brojnosti *A. pisum* na lucerki.

Ključne reči: biljne vaši lucerke, brojnost, *Medicago sativa*, temperaturni uslovi, klimatske promene.

Primljeno: 26. januara 2022.
Odobreno: 8. juna 2022.

[*]Autor za kontakt: e-mail: ivana.jovicic@pesting.org.rs

Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2203285I
Vol. 67, No. 3, 2022 UDC: 636.4.085.3
Pages 285-298 Original scientific paper

THE GROWTH PERFORMANCE AND NUTRIENT DIGESTIBILITY OF PIGS FED RAIN TREE (*ALBIZIA SAMAN*) PODS AS A REPLACEMENT FOR MAIZE

Oluwakemi T. Irekhore[1*], Akintunde O. Akinsoyinu[2] and Kazeem O. Bello[3]

[1]Agricultural Media Resources and Extension Centre, Federal University of Agriculture, Abeokuta, Abeokuta, Nigeria
[2]Department of Animal Science, University of Ibadan, Ibadan, Nigeria
[3]Institute of Food Security, Environmental Resources and Agricultural Research, Federal University of Agriculture Abeokuta, Abeokuta, Nigeria

Abstract: The growth performance and nutrient digestibility of pigs fed diets containing rain tree pods (RPs) were evaluated using 20 pigs. Five diets were formulated with RP replacing maize in the control diet at 10, 20, 30 and 40%. The pigs were randomly allotted to the 5 dietary treatments, with 4 replicates of one (1) pig per replicate, and fed *ad libitum* for eight weeks. Data were collected on initial weight, final weight (FW), daily feed intake (DFI), daily weight gain (DWG), feed conversion ratio (FCR), cost per kilogram feed (CKF), and feed cost per kilogram weight gain. At week eight, the pigs were moved into individual metabolic crates for a digestibility trial. Rain tree pods, feed and fecal samples were analyzed for proximate composition, and metabolic energy was calculated following standard procedures. The apparent digestibility of dry matter, crude protein, ether extract, ash, and nitrogen-free extract were calculated. Data generated were analyzed using a one-way analysis of variance. The growth performance of pigs fed a 10% RP diet was similar to those fed a control diet. As the dietary inclusion of RP increased, the DFI, DWG and FW of the pigs decreased ($p<0.001$). The FCR increased while CKF reduced significantly ($p<0.001$) with an increasing level of RP in the diets. Apparent nutrient digestibility was depressed ($p<0.01$) with the inclusion of RP in the diets of pigs. This study concluded that the inclusion of 10% RP as a replacement for maize in the diet of growing pigs gave optimal growth performance and reduced feed cost.

Key words: growing pigs, alternative feed resource, nutritive value, feed costs.

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

Introduction

The performance of animals is influenced by their nutrition, weight, age, and physiological state. During the growing phase, pigs consume more feed, gain more weight and have better feed efficiency than those at other physiological stages. This implies that more cost is expended on pig production at this phase having in mind that 70% of total production cost is expended on feed. The reduction of feed cost, as long as performance is not hampered, will contribute substantially to maximizing the profits of the pig farmer. Hence, a regular supply of feed at reasonable prices is essential. Furthermore, a large proportion of feed cost is expended on energy. However, because pigs are bulk feeders, conventional energy feedstuffs (especially maize) are often too expensive in their rations (Adesehinwa, 2008) in this part of the world. Maize is the major energy feedstuff for pigs and constitutes about 40% or more of the diet. It, however, has conflicting demands for human consumption, industrial use and animal feed.

In most developing economies, most of the maize produced is used for human needs, as deduced from the report of FAO (2018), while excesses are insufficient for livestock use. Maize is usually in short supply and very expensive to use for feed production, while the price keeps fluctuating and can be unpredictable. The global price per tonne of maize was 159USD as of 2016, rose to 175USD by December 2017, and again fell to 161USD by June 2018 (FAO, 2018). Locally, in Nigeria, the price of maize was ₦65,000.00/tonne in 2010 but the price almost doubled (₦110,000.00/tonne) in 2019. Therefore, exploring the use of relatively cheaper, readily available and less competitive alternatives becomes crucial to economic pig production. As opined by Irekhore et al. (2016), the utilization of locally available alternative feedstuffs will ensure success and profitability in pig production. *Albizia saman* (rain tree) pods could be a potential alternative feedstuff for pigs following the report of De la Cruz (2003) that rain tree pods could substitute up to 35% of maize in animal rations because of the close similarity in their nutritional composition.

Rain trees (*Albizia saman)* are grown along roadsides and gardens as avenue trees, in parks for shade and ornamentals, and are also planted as pasture trees (Flores, 2002; Hosamani et al., 2005; Aung et al., 2016). They are fast-growing, easy to cultivate (Idowu et al., 2006) and are cultivated and/or naturalized throughout the tropics (Durr, 2001; Staples and Elevitch, 2006). Each tree yields a large quantity of 250–300 kg (Flores, 2002; Hosamani et al., 2005) of free pods annually or even up to 500–600 kg from fully grown trees (Rath et al., 2014) between December and April, depending on the region. The pods can be stored over long periods (Idowu et al., 2006) and are used as a feed supplement for cattle, sheep and goat (Flores, 2002). An earlier report (Hosamani et al., 2005) has indicated that rain tree pods have total digestible nutrients equivalent to cereal by-

products, while Rath et al. (2017) reported that the pods could be good sources of energy and protein. It was also reported that the dietary incorporation of 30% raw or processed rain tree pods did not influence the survival, weight gain and specific growth rate of *Catla catla* fry (Rath et al., 2017). However, there is a dearth of information on its economic viability as feed for pigs. Exploring the potentials of rain tree pods could serve as a means of easing the pressure on maize, lowering feed costs and encouraging a sustained increase in pig production, hence this study.

Material and Methods

Ripe rain tree pods were picked after ripening and falling from underneath trees within the University of Ibadan campus in Ibadan, Nigeria and sun-dried. Representative samples of rain tree pods were collected and analyzed for proximate composition using the method of the Association of Analytical Chemists (AOAC, 1990). The metabolic energy was estimated using the formula of Pauzenga (1985). The amino acid profile of the pods was determined by high-performance chromatography after acidic, alkaline and enzymatic hydrolysis (Dai et al., 2014). The anti-nutrient content of the pods was determined following the methods of Harborne (1998). For the determination of tannins, 1g of the milled pods was weighed into a beaker, and soaked in a solvent mixture comprised of 80 ml of acetone and 20 ml of 10% glacial acetic acid for 5 hours. The sample was filtered through a double-layer filter paper to obtain the filtrate. A set of standard solutions of tannic acid was prepared, ranging from 10 to 50 ppm. The absorbencies of the standard solution and the filtrates were read at 500 nm on a spectrophotometer.

The content of saponins was determined by weighing 2 g of the milled pods into a 250-ml beaker, and 100 ml of isobutyl alcohol were added. It was then left for 5 hours on a UDY shaker to obtain a uniform mixture. The mixture was then filtered through a Whatman No. 1 filter paper. The filtrate was transferred to a 100-ml beaker and was saturated with a magnesium carbonate solution. The mixture obtained was then filtered to obtain a clear, colorless solution and read on a spectrophotometer at 380 nm. 0 ppm to 10 ppm of standard saponin solutions were prepared from a 1000 ppm saponin stock standard solution and saturated with magnesium carbonate as above and also filtered. The absorbencies of the standard saponin solutions were also read at 380 nm to obtain the gradient of the plotted graph.

For alkaloid content determination, 2 g of the milled pods were weighed into a 100-ml conical flask, and 20 ml of 80% alcohol (ethanol) were added to give a smooth mixture which was then transferred into a 250-ml flask and more alcohol was added to make up to 100 ml. Then, 1g of magnesium oxide was added. The mixture was then digested in a boiling water bath for 1.5 hours under a reflux air condenser with occasional shaking. The mixture was filtered while hot through a

small Buchner funnel. The residue was returned to the flask and re-digested for 30 minutes with 50 ml alcohol, after which the alcohol was evaporated, and the water was added to replace the alcohol lost. When all the alcohol had been removed, 3 drops of 10% hydrochloric acid were added. The whole solution was later transferred into a 150-ml volumetric flask, after which 5 ml of zinc acetate solution and 5 ml of potassium ferrocyanide solution were added, and the content was thoroughly mixed together to give a homogenous solution. The flask was allowed to stand for a few minutes. The solution was then filtered through a dry filter paper and l0 ml of the filtrate were transferred into a separating funnel, and the alkaloids were extracted by shaking vigorously with five successive 30-ml portions of chloroform. The residue obtained was dissolved in hot water and transferred into a Kjeldahl flask with the solution. Then, 1.2 g of sucrose and 10 ml of concentrated H_2SO_4 and 0.02 g of selenium were added for digestion into a colorless solution to determine the % NH_3 by the Kjeldahl distillation method. The obtained concentration of nitrogen (%) was multiplied by a factor of 3.26 to get the total alkaloid value.

Dried pods were used to formulate five (5) growing pigs' diets at inclusion levels of 0, 10, 20, 30 and 40% as replacements for maize. Diets were formulated to meet the nutrient requirements of growing pigs (Cromwell, 2015). Other ingredients were used at the same rate for all the diets, as shown in Table 1. A sample of each diet was taken to the laboratory and analyzed for proximate composition and metabolic energy. Twenty (20) growing pigs (cross breeds) of approximately 12 weeks of age with an average live-weight of 30.8$\pm$0.17 kg were used for this experiment. The pigs were treated for ecto- and endo-parasites using ivomectin^R (subcutaneous) at a dosage of 0.2 ml/10 kg, and then they were randomly allotted to 5 dietary treatments of 4 pigs/treatment with one (1) per replicate. They were housed in well-ventilated individual pens with low walls, equipped with shallow concrete feeders and drinkers, and fed their respective diets *ad libitum*. Fresh, clean water was supplied daily all through the period of the study, which lasted for 8 weeks. Data were collected on final weight, feed intake, daily weight gain, feed conversion ratio, cost per kilogram of feed and feed cost per kilogram weight gain.

At week 8 of the feeding trial, the pigs were moved into individual metabolic crates where they were fed known quantities of their individual diets. After 3 days of adjustment, the feces voided by each pig were collected on a daily basis for 4 days. The feces collected from each pig per day were weighed, labeled and stored at a temperature of 5 °C. All the feces collected for each pig were bulked, dried, weighed, ground and representative samples were analyzed for proximate composition following the same procedure used for the diets. The apparent digestibility of dry matter, crude protein, ether extract, ash and nitrogen-free extract were calculated using data on feed intake and results of the proximate analysis. The

data generated were analyzed using the one-way analysis of variance of the SAS statistical package (SAS, 2002).

Table 1. The composition of diets containing varying levels of rain tree pods as replacements for maize fed to growing pigs.

Ingredients (%)	Diets (Rain tree pod inclusion level)				
	0% (Control)	10%	20%	30%	40%
Cassava meal	6.75	6.75	6.75	6.75	6.75
Wheat bran	25.00	25.00	25.00	25.00	25.00
Groundnut cake	15.00	15.00	15.00	15.00	15.00
Soybean meal	10.00	10.00	10.00	10.00	10.00
Maize	40.00	30.00	20.00	10.00	0.00
Rain tree pod	0.00	10.00	20.00	30.00	40.00
Bone meal	1.50	1.50	1.50	1.50	1.50
Oyster shell	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
*Vitamin-mineral premix	0.25	0.25	0.25	0.25	0.25
Analysed components					
Dry matter (%)	92.15^{a}	90.15^{b}	90.10^{bc}	89.95^{c}	89.15^{d}
Crude protein (%)	19.40^{e}	20.00^{d}	20.50^{c}	21.55^{b}	22.55^{a}
Ash (%)	7.10^{d}	7.35^{cd}	7.45^{c}	8.25^{b}	8.60^{a}
Ether extract (%)	3.90^{b}	4.20^{ab}	4.35^{a}	4.55^{a}	4.55^{a}
Crude fibre (%)	5.85^{d}	6.00^{c}	6.25^{b}	6.35^{b}	6.80^{a}
Nitrogen-free extract (%)	55.90^{a}	52.60^{b}	51.55^{c}	49.25^{d}	46.65^{e}
**Metabolic energy (MJ/kg)	12.64^{a}	12.35^{b}	12.32^{b}	12.21^{c}	11.98^{d}

*Premix (per kg) comprised of: Vitamin A 10,000,000.00 IU; Vitamin D_3 2,000,000.00 IU; Vitamin E 20,000.00mg; Vitamin K_3 2,000.00mg; Vitamin B_1 3,000.00mg; Vitamin B_2 5,000.00mg; Niacin 45,000.00mg; Calcium Pantothenate 10,000.00mg; Vitamin B_6 4,000.00mg; Vitamin B_{12} 20.00mg; Choline Chloride 300,000.00mg; Folic Acid 1,000.00mg; Manganese 300.000.00mg; Iron 120,000.00mg; Zinc 80,000.00mg; Copper 8,500.00mg; Iodine 1,500.00mg; Cobalt 300.00mg; Selenium 120.00mg; and Antioxidant 120,000.00mg; ** Calculated.

Results and Discussion

The dry matter, proximate composition, metabolic energy and selected anti-nutrients of sun-dried ripe rain tree pods

The dry matter, proximate, metabolic energy (ME) and selected anti-nutrients compositions of sun-dried ripe rain tree pods are presented in Table 2. Dried pods had a dry matter (DM) content of 95.10%, a value similar to that reported by Raja et al. (2017) but higher than values ranging between 81.73 and 85.50 reported by Hosamani et al. (2005), Esquivel-Mimenza et al. (2014) and Aung et al. (2016). The high level of DM obtained could be explained by the intensity of drying,

which was done to allow for the ease of milling, handling and storage of the pods. The value obtained for the ME (12.07MJ/kg) is in-between the values for maize offal (10.46 MJ/kg) and maize (14.35 MJ/kg). The crude protein content (15.18%) of the pod is similar to the values of 15.31, 15.6, and 15.73% reported by Hosamani et al. (2005), Sotelo et al. (1995) and Esquivel-Mimenza et al. (2014), respectively and falls within the range (12–18 %) reported by F/FRED (1994) and Flores (2002). However, Aung et al. (2016) reported a value of 18.92 %, while Rath et al. (2014) and Raja et al. (2017) reported CP of 22.25% and 19.32%, respectively. The CP value is also higher than that of maize (8–10 %) and maize offal (11%). The value obtained for the ether extract (EE) content of the pods (7.50%) is lower than the value of 10.1% reported by Oduguwa et al. (2000). The EE value is, however, higher than values for maize (4.0%) and maize offal (3.5%). The ash content of the pod is high (10.13%) in contrast to the findings of Sotelo et al. (1995). The crude fibre (CF) content (14.2%) is higher than values ranging from 10.07 to 12.5% obtained by Sotelo et al. (1995), Oduguwa et al. (2000) and Hosamani et al. (2005). The CF value is also far higher than the value for maize (2%) but can be compared to that of maize offal (12%). The NFE (carbohydrates) content (48.13%) of the pods is close to a value of 54.23% reported by Raja et al. (2017). It is, however, low compared to the 69.93% value reported by Hosamani et al. (2005).

The pods contained 20 amino acids with values generally lower than the values reported for seeds by Sotelo et al. (1995). This is obviously so because the crude protein content of the pods was lower than that of the seeds. The combination of glutamic acid plus glutamine had the highest value, 1.36 g/100 g. On an individual basis, leucine had the highest value of 0.71 g/100 g, while the least value of 0.14 g/100 g, which is a little lower than the value for maize and maize offal (0.18%), was recorded for methionine. The value recorded for lysine (0.43 g/100 g) is higher than the values for maize and maize offal.

The pods were found to contain 19.0 mg/kg of tannins. On the contrary, Aung et al. (2016) obtained higher tannin content (1.87%) in RP. The tannin value obtained could be viewed as low in comparison to a value of 7.9% reported by Ukoha et al. (2011) and the range (6–15%) reported to be present in most tropical legumes (Barry, 1999). Variations in tannin content can be attributed to differences in the method of analysis, as tannin yield is dependent on the technique of extraction, temperature, the time during the extraction process as well as pressure. The value (12.5 mg/kg) for the saponin content was also low and could be adjudged as non-detrimental to animals since Oleszek et al. (1999) reported that the lethal dose is 1,100mg/kg of body weight. A value of 21.5 mg/kg was obtained for the alkaloid.

Table 2. The chemical composition of sun-dried ripe rain tree pods.

Components	Contents
Dry matter (%)	95.10
Metabolic energy (MJ/kg)	12.07
Proximate (%)	
Crude protein	15.18
Ether extract	7.50
Ash	10.13
Crude fibre	14.16
Nitrogen-free extract	48.13
Amino acids (g/100g)	
Aspartic acid + Asparagine	1.13
Threonine	0.39
Serine	0.55
Glutamic acid + Glutamine	1.36
Proline	0.61
Glycine	0.53
Alanine	0.44
Cystine	0.19
Valine	0.58
Methionine	0.14
Isoleucine	0.37
Leucine	0.71
Tyrosine	0.45
Phenylalanine	0.41
Lysine	0.43
Histidine	0.22
Arginine	0.41
Tryptophan	0.15
Anti-nutrients (mg/kg)	
Tannins	19.0
Saponin	12.5
Alkaloid	21.5

Growth performance characteristics

The growth performance of the growing pigs varied ($p<0.05$) with the inclusion of rain tree pods (RPs) in the diets (Table 3). The final weights (FWs) of pigs fed the control and 10% RP diets were similar but higher ($p<0.001$) than FW values for pigs in other treatment groups, with values decreasing as the inclusion rate of RP increased in the diets. The FW was greatly reduced when pigs were fed diets containing RP as a total replacement for maize. Daily weight gain (0.16 to 0.49 kg) was reduced ($p<0.001$) as the inclusion level of RP increased in the diets, which supports the findings of Thomas et al. (1976), who reported reduced weight gains for goats with the inclusion of 30% of RP in concentrates. However, a report

of another study (Irekhore et al. 2016) showed that using RP to replace maize offal in the diets of weaned pigs did not affect weight gain. Hagan (2013), in a study on broiler chickens, reported that the dietary inclusion of rain tree pods did not influence growth performance. Decreased daily weight gain with increasing levels of RP in the diets can be attributed to reduced feed intake and nutrient digestibility due to the presence of anti-nutrients. This finding is in agreement with the work of Chang and Fuller (1964) who reported a lower growth rate as a result of the presence of tannins. Alkaloids, even at low levels, have been indicated to be detrimental to performance and well-being (Van Egmond et al., 2009). Nevertheless, the weight gains recorded for the pigs were within the normal range for growing pigs. This result is in accordance with the reports of Boren and Carlson (2005) and Paul et al. (2007), who observed weight gains of between 135 and 331 g/day.

Values recorded for the daily feed intake (0.82 to 1.44 kg) of the pigs followed the same trend as the weight gain. Chicco et al. (1973) also reported decreased feed intake with concomitantly reduced weight gains in pigs fed RP levels above 22%. The past work has revealed that tannins may cause the decreased feed intake and efficiency of feed utilization (Griffins, 1991; McNeil et al., 1998). It has also been reported that saponins may have an adverse effect on the productive performance of non-ruminant animals such as pigs and poultry (Liener, 2003). The growth retardation effect of saponins on poultry and pigs results from reduced feed intake, which is primarily caused by the bitter taste and foaming properties (Soetan and Oyewole, 2009). This implies that the pigs were not able to consume enough feed to meet their nutritional requirements, hence the poor performance. Although the RP diets contain higher CP levels, these could not be utilized for body protein accretion by the pigs, probably due to depressed feed consumption, reduced digestibility and lower ME values, as well as the presence of anti-nutrients which tend to bind proteins and impair their utilization. Furthermore, the high CF values of the diets could militate against higher feed intake, which would have compensated for the lower ME concentration of the diets since pigs eat to meet their energy requirement.

The feed conversion ratio (FCR) for the pigs on the different treatments (2.89–5.33) differed ($p<0.05$). The best values were obtained for pigs fed the control and 10% RP diets, while FCR became poorer as the RP level increased in the diets of the pigs. The amino acid consumed by pigs is influenced by the feed intake and digestibility of energy in the diet, while digestible energy also influences the voluntary feed intake of growing pigs fed *ad libitum* (Chiba et al., 1991a, b). The insufficiency or imbalance of energy and amino acids could cause improper growth, poor feed efficiency and the inadequate rate and efficiency of protein and fat deposition, which explains the poor performance obtained in this study.

The cost per kilogram of feed (₦29.40 to ₦52.20, the equivalent to $0.097 to $0.17) decreased ($p<0.05$) with increasing levels of RP in the diets. Reduced feed cost is based on the fact that RP was obtained free as pods often go wasted (Hosamani et al., 2005), with the cost incurred on its collection and processing. Feed cost per kilogram of weight gain of the pigs ranged from ₦139.30 to ₦155.82 ($0.45 to $0.51), with a significant ($p<0.05$) reduction when 30% of RP was included in the diet compared to control.

Table 3. The growth performance and cost-benefit of growing pigs fed varying levels of rain tree pods as a replacement for maize.

Variables	Inclusion levels of rain tree pods						
	0%	10%	20%	30%	40%	SEM	P-value
Initial weight (kg)	30.75	30.50	30.88	30.75	31.13	0.17	0.66
Final weight (kg)	58.00^{a}	56.25^{a}	51.88^{b}	47.25^{c}	39.75^{d}	1.54	<0.001
Daily weight gain (kg)	0.49^{a}	0.46^{a}	0.38^{b}	0.30^{c}	0.16^{d}	0.03	<0.001
Daily feed intake (kg)	1.44^{a}	1.44^{a}	1.35^{b}	1.20^{c}	0.82^{d}	0.05	<0.001
Feed conversion ratio	2.89^{d}	3.12^{d}	3.60^{c}	4.09^{b}	5.33^{a}	0.21	<0.001
Cost per kilogram of feed (₦)	52.20^{a}	46.50^{b}	40.80^{c}	34.10^{d}	29.40^{e}	1.88	<0.001
Feed cost per kilogram weight gain (₦)	150.60^{a}	147.64^{ab}	147.29^{ab}	139.30^{b}	155.82^{a}	2.09	<0.05
Mortality (%)	0.00	0.00	0.00	0.00	0.00	-	-

^{abcd} Means within the same row with different superscripts differ at $p<0.001$.

Apparent nutrient digestibility

The apparent nutrient digestibility by growing pigs fed diets containing RP as a replacement for maize is presented in Table 4. The values for dry matter digestibility (DMD) ranged between 55.85 and 84.67 % reducing ($p<0.05$) with the inclusion of RP in the diets. The highest value was recorded for pigs fed the control diet, and this value differed from the values observed for pigs on the other treatments. The values observed for pigs on treatments 10% of RP and 20% of RP were similar. Although the DMD value varied between the pigs on control and those on 10% of RP, the daily feed intake, daily weight gain and feed conversion ratio did not vary between them. The crude protein digestibility (CPD) with values ranging between 78.70 and 91.26 % was depressed ($p<0.05$) by the inclusion of RP in the diets. Pigs on control had the best value for CPD, while values observed for pigs on 10% of RP and those on 20% of RP were similar to this. Although the RP diets had higher crude protein values, the CPD values showed an inverse relationship with the inclusion of RP in the diets. The depressed CPD could be partly attributed to the tannin content of RP, as tannins have been implicated in depressing digestible crude protein (Brooker, 1999). Aung et al. (2016) also

reported depressed DMD and CPD with increased RP inclusion in diets of dairy cows. The higher CF values of the RP diets could have contributed to the lower digestibility as it has been reported that an increase in the dietary level of fibre decreases nutrient digestibility, particularly protein digestibility (Cole et al., 1967; Sauer et al., 1991).

The ether extract digestibility (EED) with a range of 95.1 to 97.5% varied ($p<0.05$) across the treatments. This also followed a downward trend with the increase in the RP content of the feeds. Values for the ash digestibility (48.3–80.3%) and the nitrogen-free extract digestibility (52.1–86.9 %) were also reduced ($p<0.01$) for the pigs that received the RP diets. The depression in the apparent digestibility of the dietary nutrients observed for the pigs fed the RP diets can also be attributed to the anti-nutrient content of RP. Tannins could form soluble, insoluble or sometimes irreversible complexes with proteins, digestive enzymes and possibly starch and inhibit intestinal enzymes (Kumar and D'Mello, 1995; Farrell and Perez-Maldonado, 1999). Furthermore, saponins form bonds with proteins (Livingston et al., 1979), and may bind and inhibit some digestive enzymes (Hagan, 2013) and have presumably reduced nutrient absorption.

Table 4. The apparent nutrient digestibility of growing pigs fed diets containing varying levels of rain tree pods as a replacement for maize.

	Inclusion levels of rain tree pods						
Digestibility parameters	1(0%)	2(10%)	3(20%)	4(30%)	5(40%)	SEM	P-value
Dry matter	84.87^{a}	74.91^{b}	74.25^{b}	65.41^{c}	55.85^{d}	3.33	0.0011
Crude protein	91.26^{a}	85.90^{ab}	87.30^{ab}	82.10^{bc}	78.70^{c}	1.52	0.01
Ether extract	97.54^{a}	97.22^{a}	97.32^{a}	95.44^{b}	95.13^{b}	0.36	0.0091
Ash	80.31^{a}	66.71^{b}	65.87^{b}	58.57^{bc}	48.31^{c}	3.66	0.0067
Nitrogen-free extract	86.86^{a}	76.68^{b}	75.63^{b}	65.74^{c}	52.12^{d}	3.96	<0.001

^{abcd} Means within the same row with different superscripts differ at $P<0.01$.

Conclusion

The inclusion of 10% of rain tree pods in the diets of growing pigs compared favourably with the maize-based diet. However, the growth performance (in terms of final weight, feed intake, weight gain and feed conversion ratio) of the pigs was negatively influenced by the replacement of maize with rain tree pods in their diets beyond the 10% of inclusion rate. Cost per kilogram of feed reduced as the inclusion level of rain tree pods increased in the diets. Apparent nutrient digestibility was depressed with the inclusion of rain tree pods in the diets. To reduce competition for maize and to achieve optimal growth performance and cost-effective production of pigs, rain tree pods can be utilized in pigs' diets at a level of 10%.

References

Adesehinwa, A.O.K. (2008). Energy and protein requirements of pigs and the utilization of fibrous feedstuffs in Nigeria: A review. *African Journal of Biotechnology*, *7* (25), 4798-4806.

AOAC (1990). *Official method of analysis 15th ed.* Association of Analytical Chemists Washington DC U.S.A.

Aung, M., Kyawt, Y.Y., Htun, M.T., Mu, K.S., & Aung, A. (2016). Effects of inclusion of *Albizia saman* pods in the diets on performances of dairy cows. *American Journal of Animal and Veterinary Sciences*, *11* (1), 41-44.

Barry, T.N. (1999). Concluding comments on tannins and their roles in livestock nutrition. ACIAR Proceedings, Number *92*, 8-9.

Boren, C.A., & Carlson, M.S. (2005). Nitrogen requirements of swine and recommendations for Missouri. *Swine Nutrition, Agricultural MU Guide*. MU Extension, University of Missouri, Columbia.

Brooker, J.D. (1999). Tannins and their roles in livestock nutrition. In: J.D. Brooker (Ed), Tannins in livestock and human nutrition, ACIAR Proceedings, Number *92*, 2-8. Retrieved April 28, 2019, from https://www.aciar.gov.au/node/7591.

Chang, S.I., & Fuller, H.L. (1964). Effects of tannin content of grain legumes and sorghum on their feeding values for growing chicks. *Poultry Science*, *43*, 30-36.

Chiba, L.I., Lewis, A.J., & Peo, E.R. (1991a). Amino acid and energy inter - relationships in pigs weighing 20 to 50 kilograms, I. Weight and efficiency of weight gain. *Journal of Animal Science*, 69, 694-707.

Chiba, L.I., Lewis, A.J., & Peo, E.R. (1991b). Amino acid and energy interrelationships in pigs weighing 20 to 50 kilograms, II. Rate and efficiency of protein and fat deposition. *Journal of Animal Science*, *69*, 708-718.

Chicco, C.F., Garbat, S.T., & Muller, H.B. (1973). Una nota sobre el uso del fruto del saman (*Pithecolobium saman*) en la aliment acion del cerbo. *Agronomia Tropical*, *23* (3), 263-267.

Cole, D.J.A., Duckworth, J.E., & Holmes, W. (1967). Factors affecting voluntary feed intake in pigs 1. The effect of digestible energy content of the diet on the intake of castrated male pigs housed in holding pens and in metabolism crates. *Animal Production*, *9*, 141-148.

Cromwell, G.L. (2015). Nutritional requirements of pigs. Merck Manual, Veterinary Manual. Available online at www.merckvetmaunal.com/management-andnutrition-pigs/nutritional-requirements-of-pigs#v3323528

Dai, Z.L., Wu, Z.L., Jia, S.C., & Wu, G. (2014). Analysis of amino acid composition in proteins of animal tissues and foods as pre-column o-phtaldialdehyde derivatives by HPLC with fluorescence detection. *Journal of Chromatography B*, *964*, 116-127. De la Cruz, R. (2003). Acacia pods to feed chickens. BAR. Research and Development Digest, *Bureau of Agricultural Research Digest*, *5* (2), 19.

Durr, P. (2001). The biology, ecology and agroforestry potential of rain tree, *Samanea saman* (Jacq). Merr. *Agroforestry Systems, Springer*, *51* (3), 223-237.

Esquivel-Mimenza, H., Ibrahim, M., Harvey, C.A., Benjamin, T., & Sinclair, F.L. (2014). Pod availability, yield and nutritional characteristics from four fruit bearing tree species dispersed in pasture as a complementary feed for animal production in the dry tropics. *Livestock Research for Rural Development*, 26, Article #164 FAO (2018). Food Outlook – Biannual Report on Global Food Market, November, 2018. Rome.

Farrell, D.J., & Perez-Maldonado, R.A. (1999). Tannins in feedstuffs used in the diets of pigs and poultry in Australia. In: J.D. Brooker (Ed), *Tannins in livestock and human nutrition,* ACIAR Proceedings, Number *92*, 24-29.

F/FRED (1994). Forestry/Fuelwood Research and Development Project (F/FRED). *Growing Multipurpose Trees on Small Farms* (2nd ed.). Module 9. Species fact sheets. Bangkok, Thailand. Winrock International.

Flores, E.M. (2002). *Samanea saman* (Jacq.) Merr. In: J. A. Vozzo (ed). Tropical tree seed manual. Agriculture handbook 721. USDA Forest Service, Washington DC.

Griffins, D.W. (1991). Condensed Tannins. In: J.P.F. D'Mello, C.M. Duffus & J.A. Duffus (Eds.), Toxic substances in crop plants, (pp. 285-325). Cambridge: The Royal Society of Chemistry.

Hagan, M.A.S. (2013). Nutritive value of *Samanea saman* seed and whole pod meals as feed ingredients for broiler chickens. Kwame Nkrumah University of Science and Technology, Kumasi Report.

Harborne, J.B. (1998). *Phytochemical Methods. A Guide to Modern Techniques of Plant Analysis.* Chapman & Hall. London, New York.

Hosamani, S.V., Gowda, N.K.S., & Kololgi, S.D. (2005). Evaluation of chemical, nutritive and feeding value of rain tree pods. *Karnataka Journal of Agricultural Science*, *18* (1), 110-113.

Idowu, A.B., Babalola, O.D., & Ademolu, K.O. (2006). The physiological impact of the consumption of *Albizia saman* pods by albino rats. *Journal of Animal and Veterinary Advances, 5* (7), 585-589.

Irekhore, O.T., Akinsoyinu, A.O., Babatunde, G.M., & Bello, K.O. (2016). Replacement of rain tree (*Albizia saman*) pods for maize offal in the diet of weaner pigs: Effect on performance, carcass and blood profile. *Journal of Animal Production Research*, *28* (1), 329-339.

Kumar, R., & D'Mello, J.F.P. (1995). Anti-nutritional factors in forage legumes. In J.F.P. D'Mello & C. Devandra (Eds.), *Tropical legumes in Animal Nutrition* (pp. 95-134), Wallingford, Oxon, CAB International.

Livingston, A.L., Knuckles, B.E., Edward, R.H., deFremery, D., Miller, R.E., & Kohler, G.O. (1979). Distribution of saponins in alfalfa protein recovery systems. *Journal of Agriculture and Food Chemistry*, *27* (2), 362-365.

Liener, I.E. (2003). Plant anti-nutritional factors: Detoxification. In: *Encyclopedia of Food Sciences and Nutrition,* Second Edition (pp. 4587-4593), New York, Academic Press.

McNeil, D.M., Osborne, N., Komolong, M.K., & Nankervis, D. (1998). Condensed tannins in the Genus *Leucaena* and their nutrition significance for ruminants. In: H.M. Shelton, R.C. Gutteridge, B.F. Mullen, & R.A. Bray (Eds.), *Leucaena– Adaptation, quality and farming systems,* (pp 205-214), Cambera, ACIAR.

Oduguwa, O.O., Fanimo, A.O., Onyekwere, E.A., Oyenuga, A.B., & Sobogun, G.O. (2000). Utilization of raw and autoclaved whole pods of *Samanea saman* (Jacq. Merril) by the domestic rabbit. *Tropical Agriculture (Trinidad)*, *77* (3), 194-198.

Oleszek, W., Junkuszew, M., & Stochmal, A. (1999). Determination and toxicity of saponins from *Amarathus cruentus* seeds. *Journal of Agriculture and Food Chemistry*, *47* (9), 3685-3687.

Paul, S.S., Mandal, A.B., Chatterjee, P.N., Bhar, R., & Pathak, N.N. (2007). Determination of nutrient requirements for growth and maintenance of growing pigs under tropical condition. *Animal*, 1, 269-282.

Pauzenga, U. (1985). Feeding Parent Stock, *Zootechnica International*, 22-23.

Raja, K.K., Srinivas, K.D., & Raghava, R.E. (2017). Chemical composition and in-vitro evaluation ofrain tree pods as a livestock feed. *International Journal of Science, Environment and Technology, 6* (5), 3105-3109.

Rath, S.C., Nayak, K.C., Mohanta, K.N., Pradhan, C., Rangacharyulu, P.V., Sarkar, S., & Giri, S.S. (2014). Nutritional evaluation of rain tree (*Samanea saman*) pod and its incorporation in the diet of rohu (*Labeo rohita* Hamilton) larvae as a non-conventional feed ingredient. *Indian Journal of Fisheries*, *61* (4), 105-111.

Rath, S.C., Nayak, K.C., Pradhan, C., Mohanty, T.K., Sarkar, S., Mohantan, K.N., Paul, B.N., & Giri, S.S. (2017). Evaluation of processed rain tree (*Samanea saman*) pod meal as non-conventional

ingredient in the diet of *Catla catla* fry. *Animal Nutrition and Feed Technology*, *17* (2), 323-332.

SAS (2002) SAS/STA Statistical Analytical Systems Users' Guide (Release 9.1 Edition). SAS Institute Inc. Cary, North Carolina.

Sauer, W.C., Mosenthin, R., Ahrens, F., & den Hartog, I. (1991). The effect of source of fibre on ileal and faecal amino acid digestibility and bacterial nitrogen excretion in growing pigs. *Journal of Animal Science*, *69*, 407-487.

Soetan, K.O., & Oyewole, O.E. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *African Journal of Food Science*, *3* (9), 223-232.

Sotelo, A., Contreras, E., & Flores, S. (1995). Nutritional value and content of anti-nutritional compounds and toxics in ten wild legumes of Yucatan Peninsula. *Plant Food for Human Nutrition*, *47* (2), 115-123.

Staples, G.W., & Elevitch, C.R. (2006). *Samanea saman* (rain tree), ver. 2.1. In: C. R. Elevitch (Ed.), Species profiles for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Holualoa, Hawai'i. Retrieved January 25, 2019 from http://www.traditionaltree.org

Thomas, C.T., Devasia, P.A., Nandakumaran, M., & Sukumaran, M.V. (1976). Studies on feeding goats II. Evaluation of rain tree (*Enterolobium saman or Samanea saman*) fruit meal. *Kerala Journal of Veterinary Science*, *7*, 7.

Ukoha, P.O., Cemaluk, E.A.C., Nnamdi, O.L., & Madus, E.P. (2011). Tannins and other phytochemicals of *Samanaea saman* pods and their antimicrobial activities. *African Journal of Pure and Applied Chemistry*, *5* (8), 237-244.

Van Egmond, H., Schothorst, R., & van den Top, H. (2009). Alkaloids in feed and food: an emerging risk? Lecture in: 3rd International Feed Safety Conference – Methods and Challenges, Wageningen, The Netherlands.

Received: June 17, 2020
Accepted: June 8, 2022

PERFORMANSE U TOVU I SVARLJIVOST HRANLJIVIH MATERIJA KOD SVINJA HRANJENIH MAHUNAMA KIŠNOG DRVETA (*ALBIZIA SAMAN*) KAO ZAMENE ZA KUKURUZ

Oluwakemi T. Irekhore[1*], Akintunde O. Akinsoyinu[2] i Kazeem O. Bello[3]

[1]Centar za poljoprivredne medijske resurse i savetodavstvo, Federalni poljoprivredni univerzitet, Abeokuta, Abeokuta, Nigerija
[2]Odsek za stočarstvo, Univerzitet u Ibadanu, Ibadan,
[3]Institut za prehrambenu sigurnost, ekološke resurse i poljoprivredna istraživanja, Federalni poljoprivredni univerzitet Abeokuta, Abeokuta, Nigerija

R e z i m e

Performanse u tovu i svarljivost hranljivih materija kod svinja hranjenih mahunama kišnog drveta, determinisano je u istraživanju na 20 svinja. Pet smeša je formulisano tako što je kukuruz iz kontrolne smeše zamenjen sa 10, 20, 30 ili 40% mahuna kišnog drveta. Svinje su nasumično raspoređene u 5 tretmana ishrane, sa 4 ponavljanja i jednim grlom po ponavljanju, pri čemu su hranjene *ad libitum* tokom osam nedelja. Registrovani su podaci o početnoj telesnoj masi, završnoj telesnoj masi (ZTM), dnevnom konzumiranju hrane (DKH), dnevnim prirastima (DP), konverziji hrane (KH), ceni hrane (CH) i troškova ishrane po kilogramu ostvarenog prirasta. Tokom osme nedelje, svinje su prebačene u pojedinačne metaboličke kaveze radi ispitivanja svarljivosti. Mahune kišnog drveta, uzorci hraniva i fecesa analizirani su standardnom hemijskom analizom, dok je metabolička energija izračunata korišćenjem standardnih procedura. Izračunata je prividna svarljivost suve materije, sirovih proteina, sirovih masti, pepela i bezazotnih ekstraktivnih materija. Dobijeni podaci su analizirani korišćenjem jednofaktorske analize varijanse. Proizvodne karakteristike svinja koje su hranjene smešom sa 10% učešća mahuna kišnog drveta, bile su slične kontrolnoj grupi. Povećavanje učešća mahuna kišnog drveta u smešama, dovelo je do smanjenja DKH, DP i ZTM svinja ($p<0,001$). Utrošak hrane za jedinicu prirasta se povećevao dok se CH značajno smanjivala ($p<0,001$) sa povećanjem nivoa mahuna kišnog drveta u obroku. Prividna svarljivost hranljivih materija bila je smanjena ($p<0,01$) sa uključivanjem mahuna kišnog drveta u konzumiranim smešama. Iz ovog istraživanja se može zaključiti da uključivanje 10% mahuna kišnog drveta kao zamene za kukuruz u obroke za svinje u porastu daje optimalne tovne performanse uz smanjene troškove ishrane.

Ključne reči: svinje u porastu, alternativna hraniva, hranljiva vrednost, troškovi ishrane.

Primljeno: 17. juna 2020.
Odobreno: 8. juna 2022.

[*]Autor za kontakt: e-mail: raykemi@yahoo.com

Journal of Agricultural Sciences (Belgrade) https://doi.org/10.2298/JAS2203299E
Vol. 67, No. 3, 2022 UDC: 551.583(669)
Pages 299-320 Original scientific paper

ASSOCIATING FARMERS' PERCEPTION OF CLIMATE CHANGE AND VARIABILITY WITH HISTORICAL CLIMATE DATA

Jane O. Ezeh[1], Edith U. Madukwe[1] and Christopher U. Ezeh[2,3*]

[1]Department of Nutrition and Dietetics, Faculty of Agriculture, University of Nigeria, Nsukka
[2]Department of Geography, Faculty of the Social Sciences, University of Nigeria, Nsukka
[3]WASCAL Centre, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract: The farmers' perceptions of climate change (CC) and variability in Okpuje were assessed and compared with historical climate data. They perceive an occurrence of change that affects their farm activities, but lack the scientific understanding of this change. While some do not know what causes the change, others attribute it to God's vengeance. The perceptions of rising temperature and delay in the onset of the rainy season are corroborated by the analysis of the climate data. The temperature is significantly rising and it increased at the rate of 0.14°C per decade between 1960 and 2019. The rainfall decreased at the rate of 8.5 mm per decade. The rainy season tends toward late-onset and early cessation dates. However, the perception of increasing rainfall in the area was not upheld by the trend analysis of the rainfall data. The difference might be due to high variability in rainfall in space and time. The high rainfall recorded lately might have posed difficulty for the human memory as closer events are remembered easier than distant events and hence can be unravelled via a scientific approach. Nevertheless, since perception shapes adaptation, the people's indigenous perceptions and experiences should form part of intervention measures and policies for CC adaptation to command greater participation and wider acceptance. Thus, farmers' perceptions provide vital information but would be more reliable if integrated with scientific data analysis for policy and decision-makers in CC science, implying that none of them should be relegated but integrated.

Key words: climate change and variability, rainfall, temperature, perception, Nigeria.

*Corresponding author: e-mail: Christopher-uche.ezeh@unn.edu.ng

Introduction

Climate change is a global menace that affects all sectors of the economy and particularly food security (Clarke et al., 2012; Ayanlade et al., 2017). The global temperature is rising, coupled with changing rainfall patterns. The global mean temperature rose by 0.8°C in the past century and is likely to increase by 1.5 to 4.8°C in the next century if nothing is done to reduce emission levels (IPCC, 2014; Hansen et al., 2006; Shankar, 2018). The temperature rise has already triggered some extreme events like heatwaves and droughts. The rainfall patterns are also changing, however, this change has many uncertainties, unlike the temperature change (Byakatonda et al., 2019). Certain regions will experience an increase in rainfall, while in others, it may decrease or become more erratic. Also, the impacts of climate change are uneven in a way that the developing countries are more vulnerable than the developed world. Sub-Saharan Africa is also likely to experience higher impacts of climate change (Sylla et al., 2016) in terms of extreme warming with little increase in precipitation in some parts (Abegaz and Wims, 2015).

Hence, Sub-Saharan Africa is regarded as one of the most vulnerable regions to climate change (Ayanlade et al., 2017). This obtains from the fact that its high dependence on rain-fed agriculture is worsened by a high level of poverty. Furthermore, the poor rural farmers of the region are more vulnerable to climate change and variability owing to high dependence on rain-fed agriculture and poor technological and infrastructural development (Lipper et al., 2014; Adimassu and Kessler, 2016). The increasing occurrence of extreme events could modify the climatic patterns, thereby affecting bio-resources and food production, which would lead to food insecurity (Shankar, 2018). The extent to which the impacts of climate change are felt is principally dependent on the extent of the adaptive capacity of the people or location (Gbetibuo, 2009). Hence, poor rural farmers whose livelihoods depend on the exploitation of natural resources are likely to be more vulnerable (Gbetibuo, 2009).

Climate change in terms of rainfall and temperature changes has impacted crop production in many countries, especially wheat and maize yields (Porter et al., 2014). Most of the major crops in the study area are vulnerable to climate change, such as cocoyam, yam, groundnut, beans, maize, cowpea, and paw-paw. Rising heat and dryness significantly reduce yields of maize, soybeans, wheat, and yam, but the effects on rice and cassava are not significant (Jarvis et al., 2012; Porter et al., 2014; Del Rio and Brent, 2014; Matiu et al., 2017). Mannack (2009) has shown that a shortfall of 4 million metric tonnes of maize occurs due to drought damages to maize in southern Africa. Kaye and Quemada (2017) have hinted that climate change increases the incidences of erosion and leaching, which affect soil fertility. Hence, climate change negatively affects agricultural productivity (Nelson et al.,

2014; Morton, 2017). For instance, cocoyam in southern Nigeria has been affected severely by climate change (Tunde, 2011; Ukonze, 2012; Ifeanyi-obi et al., 2016, 2017; Ifeanyi-obi and Togun, 2017). A temperature increase of a degree Celsius in Nigeria could lead to a reduction in crop yield (Olakojo and Onanuga, 2020). Irregular and unpredictable rainfall and sunshine hours lead to a 2.4% decline in the productivity of yam, maize, melon, and sorghum (Idowu et al., 2011). The challenges of climate change are worsened by low adaptation strategies due to low income (Enete et al., 2011), which reduces the coping strategy and leads to food insecurity.

In Nigeria, the problem of food insecurity is aggravated due to several other factors, such as neglect of agriculture for the oil-driven economy, conflicts, and climate disasters like flooding and droughts (Fasoyiro and Taiwo, 2012). There have been increasing impacts of climate change on agricultural production via the high frequency of drought events and flooding (Laux et al., 2010; Watkiss et al., 2012; Makame and Shackleton, 2019). Though climate projection has been able to provide information on the impact of climate change on global and regional levels, local-level studies with the rural farmers cannot be overlooked as they will provide first-hand information based on their experiences with the climate effects on their livelihoods. The perceptions of climate change and variability are informed by personal experiences and knowledge of the stimulus (Brown and Besner, 2004 cited by Makame and Shackleton, 2019). However, the ability to relate the experiences, including their scientific basis, is enhanced by educational status. Such knowledge of how the locals perceive climate change is known to be critical to examining their vulnerability, responses, and initiating adequate adaptation strategies (Adelekan and Gbadegesin, 2005; Gbetibuo, 2009).

Perception in this content entails the approaches through which the people understand their environment and so can utilise the environmental resources and acquire the capability to adapt to the stimuli that may arise from their interactions. Perceptions also relate to aspects of the environment or climate which form part of the individual's everyday experiences, prompting them to adjust to certain climate variability that affects their livelihood (Cuni-Sanchez et al., 2019; Makame and Shackleton, 2019). Such experiences make a farmer, for instance, opt for early maturing crops if the rains become more erratic or the growing season becomes shorter. Such actions might have been done without any scientific analysis of climate data or recommendations from scientists (Teka and Vogt, 2010). However, extreme events such as heatwaves, droughts, and floods may push the perception beyond the 'perceptual threshold of human experience' (Whyte, 1985; Makame and Shacklton, 2019). Normal climates might be perceived and interpreted differently among individuals based on key livelihood experiences, culture, memory, and resilience (Adger et al., 2009), which also vary with the exposure, education, and income levels.

Several studies explore the correlation of rural farmers' perceptions of climate change and climate variability with climate data. Such studies include Makame and Shackleton (2019) in Zanzibar, where they find that the perceptions of the local communities are influenced by the relations between the elements and the people's livelihood activities and their recall of past climate. Also, Rapholo and Makia (2020), working in South Africa, find that the perception of 64% of the farmers was consistent with results from meteorological data. Amadou et al. (2015) got similar results in the Upper East region of Ghana. Cherinet and Mekonnen (2019), in Ethiopia, have found that the perception of the people is in agreement with meteorological data showing that temperature is rising, but rainfall is decreasing as the onset date is later than before. The study of Etana et al. (2020), in central Ethiopia, finds that the perception of the farmers on temperature increase fairly aligns with the climate data but disagrees with the rainfall. Also, in Ghana, the result from climate data showing a rising trend in rainfall, temperature, and wind speed is corroborated by the people's perception. The findings of the study conducted by Limantol et al. (2016) over the Vea catchment in Ghana have revealed the climatic data is in agreement with the people's perception that temperature is rising but is incongruent with their perception of decreasing rainfall amount, duration, and intensity. In Burkina Fasso, Sanfo et al. (2014) find that the climate data is in agreement with people's perceptions, except for the perception of rising solar radiation.

In Nigeria, several studies have been done on farmers' perceptions of climate change and variability. However, only a few attempted to compare the farmers' perceptions with the results of climate data analysis. Similar or related studies that compared rural farmers' perceptions with results from meteorological data in Nigeria include Ayanlade et al. (2017), where the perception of the majority of the respondents is in line with the results from climatic data in Southwestern Nigeria. Falaki et al. (2013), in north-central Nigeria, find the farmers' perception to agree with climate data in north-central Nigeria. Based on the authors' search, there has been none so far conducting a similar study in the southeastern part of Nigeria. Yet, it is a region that is losing its forest resources widely due to rapid urbanization. Though there is no need to validate farmers' perceptions with climate data, their congruence boosts the level of confidence in the findings (Makame and Shackleton, 2019). Therefore, the study will achieve the goal by finding the perception of the farmers, investigating the trends in rainfall and temperature data, predicting the onset dates of the rainy season, and comparing the findings from the two dimensions.

Material and Methods

Study area

The study was done in Okpuje, a fast-growing rural farming community in the Nsukka local government area of Enugu State, Nigeria. Its location is in the northwestern part of Nsukka (Ijere, 1976; Nwamarah et al., 2015). Its geographical location is between 6.76^{O}N and 6.95^{O}N and longitude 7.20^{O}E – 7.33^{O}E (Figure 1). The area covers a landmass of about 65km^{2} (Nwamarah et al., 2015). It has 12 villages that comprise Amafor, Ama-ozzi, Echara, Ejuona,Ibeku, Mkwurushi, Okpuje-ani, Okpuje-eti, Ewo-noya, Iga, Uhu-Asama, and Umuhu. Okpuje shares a border with Okutu to the north, Ibagwa-ani and Ibagwa-agu to the east, Anuka to the west, south with Edem and to the southwest with Uzouwani LGA.

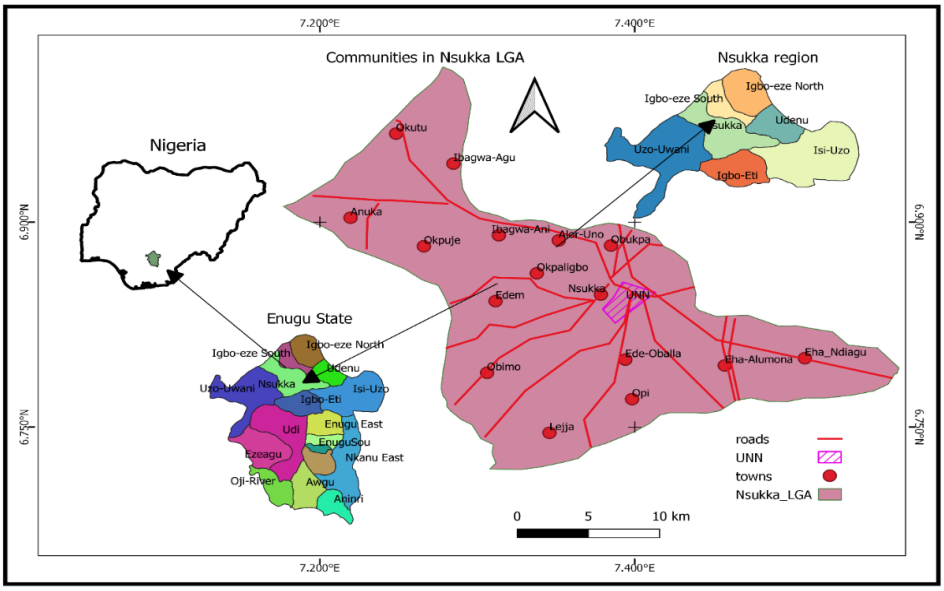

Figure 1. The study area (Okpuje).

Okpuje had a population of 8021 persons in 1991 (NPC, 1991), which was projected to be 18351 persons in 2019. Its mean annual rainfall and temperature are 1720 mm and 26.5^{o}C, respectively (Sunday and Oghenenyoreme, 2014). The rainy season extends from April to October, and a dry season from November to March (Nwamarah et al., 2015) (Figure 2).

Data

The study population

The study population was drawn from households within Okpuje. These households make up the sampling frame for the survey study, while village leaders comprise the key informants. Households here comprise all people who live together and share a common food source, eat together and have a sense of belonging together as one social unit (NPC, 2006). The household's heads are males or females who are farmers and have attained the age of 45 and above. The age bracket was chosen as they were considered to be able to describe the changes and variability in climate of the area in the past and present based on their experiences over time. The aged will likely give more reliable information than the youths who may not have been born at the time or period under investigation. Besides, the younger ones might not have had the experiences and might not be cognizant of the happenings in their surroundings like the elderly. Moreover, it has been shown that elderly people have more experiences and always have a higher probability among all age brackets of giving reliable information on the variability of the climate of their area (Amadou et al., 2015; Cherinet and Mekonnen, 2019; Etana et al., 2020).

The community's population comprises 9078 males and 9273 females (NPC, 1991) of 110 clans and 12 villages.

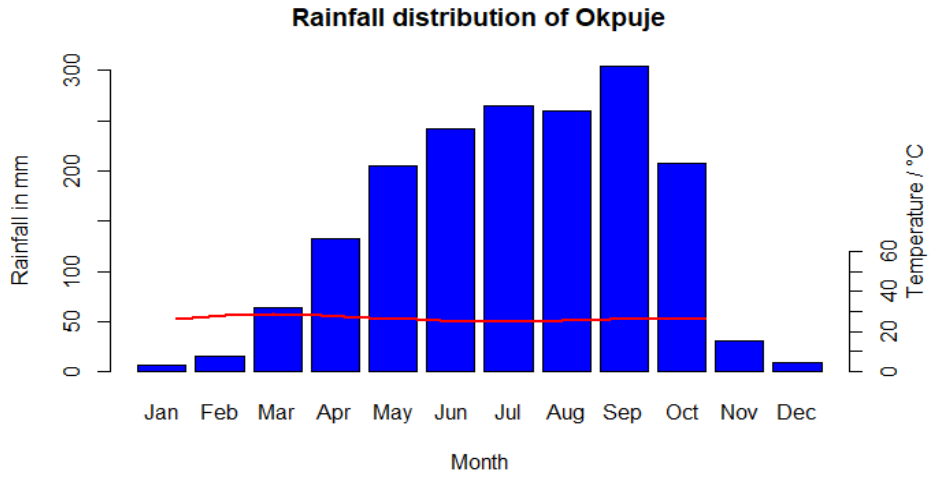

Figure 2. The mean monthly rainfall sum and temperature in the Okpuje area.

Study design

The study comprised both primary and secondary data. The primary data were a cross-sectional study using a mixed (quantitative and qualitative) method. A

semi-structured questionnaire was used for the quantitative study, while interviews involving key informants and focus group discussions were used for the qualitative study. Historical climate data were the secondary data.

Sample size and sampling technique

Determining the sample size using households could not be done as there was no information on the number of households in the villages. However, the number of clans that are known was used to determine the number of respondents for the study. Thus, 344 eligible households were selected from the 86 clans randomly chosen out of the 110 clans though some clans were deliberately dropped for security reasons. The selected households were included in the study based on a number of criteria that included: farming being their only source of income; having an adult female or male farmer of 45 years and above, and having resided in the community for over 30 years. The households comprised 47.9% of males (163) and 52.1% of females (177). Two groups of focus group discussions (FGDs) comprising eight persons each and twelve key informant interviews were conducted. The FGDs were included in order to gain an in-depth understanding of the farmers' perception of climate change in the area. It helped to strengthen, corroborate, or permit cross-comparisons of the data (Kitzinger, 1994). Copies of the questionnaire were distributed to get information on their perception of climate change, particularly changes in temperature, rainfall distribution, its onset, and dry spells. The questionnaire comprised close-ended questions from which the respondents chose the one that suits their situation with a few open-ended questions. Additionally, several other questions were posed to the respondents on the cause of the change. Also, follow-up discussions were instigated with the respondents to get more information on the variability of weather and climate.

Historical climate data

Rainfall and temperature data were retrieved from the Climate Prediction Centre Merged Analysis of Precipitation (CMAP) for the Nsukka area. The CMAP has a spatial resolution of 2.5 by 2.5 and has a global coverage (Xie and Arkin, 1997; Xie et al., 2007). The temporal resolution of the data is daily and the period accessed covers sixty years from 1960 to 2019. It is freely accessed and downloaded from https://psl.noaa.gov/data/gridded/data.cmap.html. The data were divided into two periods, from 1960 to 1989 and from 1990 to 2019. This was done to learn the magnitude of change between the two periods as it is postulated that significant global warming started after the 1980s (Hansen et al., 2006; Swanson et al., 2009). This is necessary to identify change, especially as rainfall and temperature are key measures of changing climate (Hansen et al., 1996, 2006). The rainfall and temperature data were then used to do trend analysis and estimate the onset and cessation dates of the rainy season (see section 2.3).

Data Analysis

Primary data

The quantitative data were entered into the Statistical Package for Social Sciences (SPSS) version 25 for analysis. The perception of climate variability and change were subjected to simple analyses like frequencies, mean, and percentages.

Historical climate data

The rainfall and temperature data were analysed with the Mann-Kendall trend test (equations 1–3) (Mann, 1945; Kendall, 1975) using the 'trend' package (Pohlert et al., 2016) in the R software, which is freely available at https://cran.r-project.org/. A positive (negative) value denotes a rising (decreasing) trend. The standard Z statistic is calculated and used to test for significance (equation 3). It tests the null hypothesis that if Z is greater than alpha (0.05), then the null hypothesis is rejected, meaning there is a significant trend. If the trend is positive, then it denotes an increasing trend, but if the reverse holds, then the trend is decreasing (Ceribasi et al., 2013; Ceribasi et al., 2014; Ahmad et al., 2015; Alemu and Dioha, 2020; Hu et al., 2020). The computational techniques for the Mann-Kendall test take account of time series of unknown data points (n) where Ti and Tj are subsets of the data where i = 1, 2 …, n-1, and j = i+1, i+2…n (Motiee and McBean, 2009). Each data Ti becomes a reference point and compares with all the data points Tj as shown in equations 1 and 2.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(T_j - T_i\right) \quad (1)$$

$$sign\,(T) = \begin{cases} 1\ if & T > 0 \\ 0\ if & T = 0 \\ -1\ if & T < 0 \end{cases} \quad (2)$$

where T_j and T_i are values per annum in years j and i, j > 1 (Motiee and McBean, 2009).

Thus for S > 0, the later observations in the series tend to be larger than the earlier observations, and if S < 0, then the reverse holds.

Hence, the variance of S is given by the relationship in equation (3) for n ≥ 10.

$$\mathrm{var}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{t} f_t\left(f_t - 1\right)\left(2f_t + 5\right) \right] \quad (3)$$

where $_t$ varies over a set of tied ranks, f_t is the frequency of occurrence of $_t$.

Therefore, the Mann-Kendall test calculates the Z-statistic using equation 4.

$$Z = \begin{cases} (S - 1/\sigma) & S > 0 \\ 0 & S = 0 \\ (S + 1/\sigma) & S < 0 \end{cases} \quad 4$$

The Kendall correlation coefficient (tau) is given by the relationship in equation (5).

$$\tau = \frac{S}{[n(n-1/2)]} \quad 5$$

The rainfall data were also used to determine the dates of the onset and retreat of the rainy season using Anyadike's method (equation 6).

$$ORD = \frac{DM(0.083Tr - Ac)}{RM} \quad 6$$

where ORD is the date of the onset/retreat of the rainy season, DM is the number of days in the month that contain the rain amount greater than or equal to (Tr * 0.083), and Ac is the rains accumulated in the months preceding the month that has the value of (Tr * 0.083), Tr is the total annual rainfall, and RM is the total amount of rain in the very month that has (Tr x 0.083) (Anyadike, 1993). The formula is applied in reverse order by accumulating rainfall total backward from the end of the year to obtain the real date of retreat (Anyadike, 1993; Ezeh et al., 2021).

Results and Discussion

The rainfall and temperature distribution of the area

The area has a high annual rainfall of 1733.1 mm and a mean annual temperature of about 26.4°C. The lowest annual rainfall of 1292 mm was recorded in 1983, while the highest recorded was 1958.6 mm in 1995. The wettest month is September, followed by July (Figure 2). The driest months are from December to February. The lowest mean annual temperature was recorded in 1975 and 1976 (25.6°C), but the highest was in 2016 (27.1°C). The hottest months are March (28.6°C), February (28.2°C), and April (28°C).

Rainfall: perceived and inferred from climate data

More than half of the respondents claim to be aware of climate change while 24% say that they do not know about climate change. They assert that they have heard of climate change, however, over 58% of the respondents lack a scientific understanding of what climate change is. Most of the farmers have no idea of the causes of climate change, as claimed by 81% of the respondents, while 16% attribute it to cosmological powers or the 'Gods'.

On the perceived changes in rainfall over time, 95% of the respondents say that they have observed changes in the rainfall of the area. Of these, over 59% show they have observed increasing rainfall and polluted rain, 54%, and 52% have observed a delayed onset of the rainy season and erratic or irregular rainfall, respectively (Table 1). Similar responses were obtained from the Focus Group Discussions (FGDs).

Table 1. The observed change in the annual rainfall of the area as perceived by the respondents.

Variables	Frequency	Percentages
Changes observed in rainfall		
Yes	328	96.2
No	13	3.8
The observed changes		
Increasing rainfall	194	59.10
Reducing rainfall	27	8.20
Delayed rainfall	176	53.70
Too early rainfall	9	2.70
No change	15	4.60
Do not know	2	0.60
Acid rainfall	194	59.10
Irregular rainfall	172	52.40
Turbulent rainfall	40	12.20

The variabilities in rainfall are depicted in the plot of their deviations in Figure 3. It reveals the inter-annual variability such that the decades 2000–2019 were the driest as most of the years had rainfall below the mean. Only 5 years had annual rainfall above the mean, unlike the preceding decades. The trend analysis of the rainfall indicates a negative trend (Figure 4).

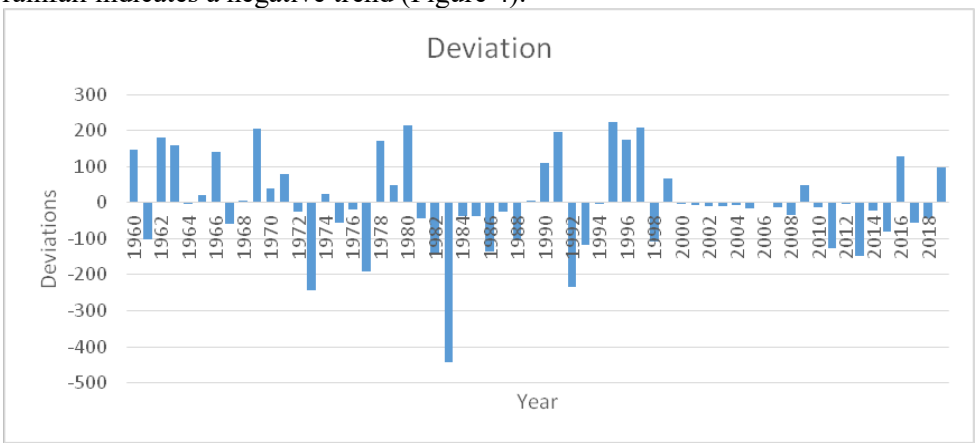

Figure 3. Deviations in the annual rainfall over the years.

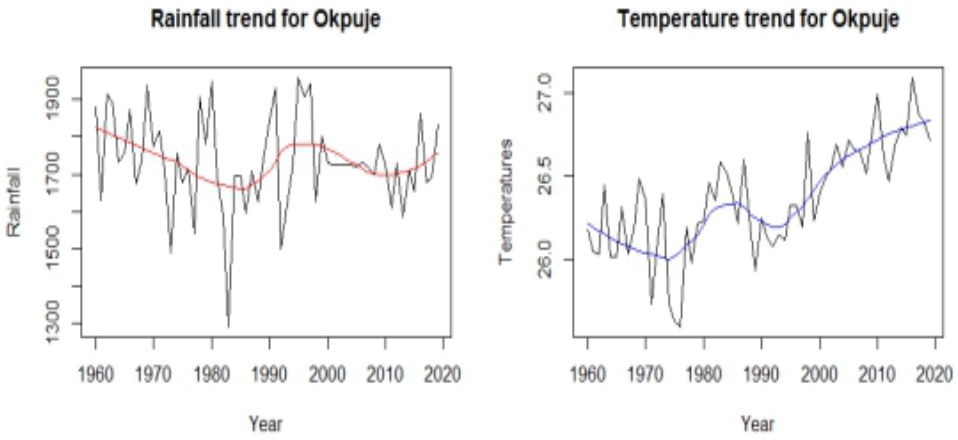

Figure 4. Annual rainfall and mean annual temperature trends of Okpuje from 1960 to 2019.

However, when broken into two periods of pre-change (1960–1989) and change periods (1990–2019), the magnitude of change reduced in the change period from 5.85 mm to 2.43 mm per annum (Tables 2 and 3). The pre-change period is significant, while the change period is not significant. This shows that rainfall decreased over the years, though, with some sort of rain recovery in the later years.

Table 2. The trend analysis of the annual rainfall and mean annual temperature from 1960 to 2019.

	Tau	Z	Sen's slope	P-value
Rain	-0.11	-1.21	-0.85	0.23
Temp	0.54	6.11	0.014	0.014

*Tau defines the strength of the monotonic relationship; Z-statistic is the standard normal deviate that determines when the null hypothesis is to be rejected or not.

Table 3a. The trend analysis for the annual rainfall and mean annual temperature in Okpuje from 1960 to 1989.

	Tau	Z	Sen's slope	P-value
Rain	-0.26	-2.00	-5.85	0.046
Temp	0.18	1.41	0.008	0.15

Table 3b. The trend analysis for the annual rainfall and mean annual temperature in Okpuje from 1990 to 2019.

	Tau	Z	Sen's slope	P-value
Rain	-0.24	-1.82	-2.43	0.069
Temp	0.64	4.94	0.03	0.00000

*Tau defines the strength of the monotonic relationship; Z-statistic is the standard normal deviate that determines when the null hypothesis is to be rejected.

Temperature: perceived and inferred from climate data

Over 94% of the respondents observed changes in temperature over time in the area, while a little over 5% did not observe a temperature change. Similarly, about 99.7% of these observed rising temperatures (Table 4). Narratives from the FGDs also support the rising temperature in the area.

Table 4. The observed change in the mean annual temperature of the area as perceived by the respondents.

Changes observed in temperature		
Yes	321	94.4
No	19	5.6
The observed changes		
Increasing temperature	311	99.7
Decreasing temperature	1	0.3

The results of temperature analysis show that the temperature of the area is rising. For instance, the plot of the deviations shows that the temperature rose, with the past two decades being the hottest over the study period (Figure 5).

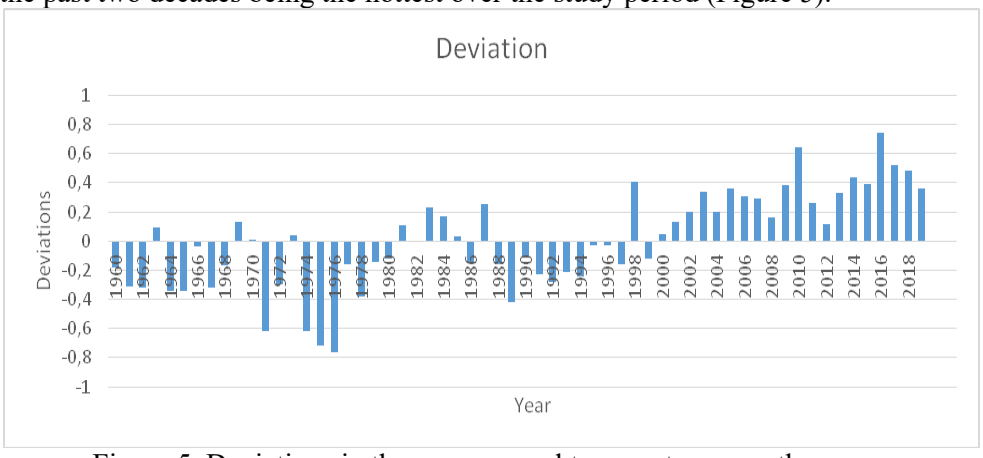

Figure 5. Deviations in the mean annual temperature over the years.

The decades 2000 to 2019 had their temperatures above the mean, while from 1960 to 1969, their temperatures were below the mean except for 2 years (Figure 5).

The trend analysis of the temperature data reveals a significantly increasing trend (Figure 4). When divided into two periods of pre-change and change periods, the magnitude of the trend rose from 0.008 to 0.03. While the pre-change period is not significant, the change period is highly significant (Tables 2 and 3).

To understand the pattern of change in the onset of the rainy season, the results of the onset/cessation dates of the rainy season were subjected to trend analysis which shows that the onset of the rainy season tends towards the late onset of the rainy season while the cessation comes earlier than before (Figure 6).

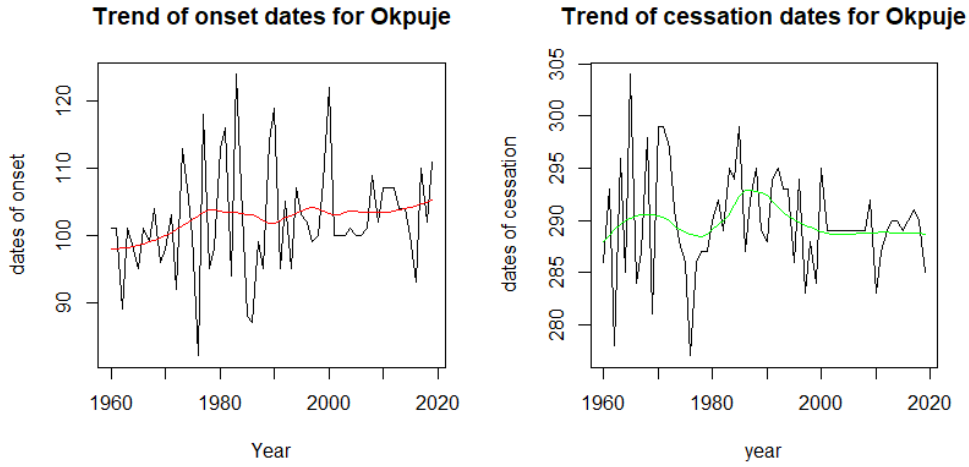

Figure 6. The trend analysis of the onset and cessation dates of the rainy season.

Namely, it has an increasing trend for the onset dates but a decreasing trend for the cessation dates. The mean onset date of the rainy season is April 12, while that of cessation is October 17.

The farmers are aware of the change happening to their environment, but none of them could mention the causes of climate change. A few, however, attributed it to the wrath of the 'Gods'. This is similar to findings elsewhere, for instance, Ogalleh et al. (2012) in Kenya, Makame and Shackleton (2019) in Zanzibar, among others. This shows they have limited scientific knowledge of climate change though they are aware of something drastic happening to their agricultural planning and productivity, such as increasing storms, rising temperature, delay in the onset of the rainy season, and irregular or erratic rainfall that affect their crops and other economic trees. This indicates a low to medium knowledge of climate change, which agrees with the UNDP (2010) report that there is a low level of climate change awareness in Nigeria. This has a negative implication on their

adaptation and mitigation strategies because what you do not adequately understand or lack sound knowledge of, you may not find a solution to it (or you cannot find the most accurate solution to it). The literature shows a strong correlation between farmers' awareness and perception of climate change and their adaptation to its impacts (Adger et al., 2009; Debela et al., 2015). Farmers' sound knowledge of climate change and their responses to climatic threats will shape their adaptation alternatives and outcomes (Pauw, 2013; Debela et al., 2015). Similarly, Olorunfemi (2010) adds that inadequate awareness and knowledge are a major setback to reducing the impacts of climate change in Nigeria.

The perception of the farmers is that there are notable changes in rainfall intensity, delay in the onset of the rainy season, and erratic rainfall. The views were corroborated by FGDs and narratives from some respondents stating that:

"Rain falls and ceases making the already planted crops die-off". "Excess heavy rainfall kills all crops". "Even intense sunshine without rainfall makes crops die-off" (respondent 1).

"Intensive sunshine affects all food crops by drying them up and rain affects any type of beans by washing them away" (respondent 2).

"There was excess rainfall last year which led to the destruction of some crops such as black beans and tomatoes" (respondent 3).

These views conform with Ali and Erenstein (2017) that the pattern, timing and intensity of rainfall have been altered by climate change. Onyeneke et al. (2018) add that the changing climate conditions in the southeast, which are expressed in changes in rainfall pattern, are worrisome. Related studies have also highlighted the delay in the onset of the rainy season in the southeast (Chukwuone, 2015; Nnadi et al., 2019). Their perceived increase in rainfall contradicts earlier studies across Nigeria (Ndambiri et al., 2012, Nnadi et al., 2019) but concurs with Chukwuone (2015), who finds excess rain in Enugu State. The erratic nature of rainfall in the area is corroborated by FGDs and a key informant who adds that there is no consistency in rainfall pattern in the community: "Rainfall varies yearly and it is not all years we experience heavy and much rainfall".

The perception of temperature in the area is that it is increasing. The FGD and key informant interview support this view. This is in agreement with several studies (Olayemi, 2012; Nnadi et al., 2019) that the temperature has been increasing over the years.

The comparison of observed climate change based on people's perception and climate data

The findings indicate that there is climate change in the study area based on the respondents' perceptions. They believe that there is an increase in rainfall, the delayed onset of the rainy season and irregular rainfall patterns (Table 1). Also,

they noticed that there was an increasing temperature in the study area far higher than what was obtained in the past decades.

The analysis of the climate data also indicates that there is a changing climate in the area. However, the people's perception of an increase in rainfall is countered by the results of trend analysis as the rainfall of the area has been decreasing over the years, unlike what was obtained between 1960 and 1989. The reason for the disparity might be due to the rainfall recovery in the area in 2016 and 2019. Both years have one of the highest mean annual rainfall in the last decade (Figure 3). It might be due to human weakness in keeping track records over a long period as the memory will more quickly cognize the most recent event than the distant past. Also, rainfall is highly variable and poses difficulties for human memory to recall the vagaries of its occurrences. The variable nature of rainfall also poses a challenge to scientists modelling its future scenarios or projections. Related studies elsewhere in Sub-Saharan Africa have shown a disparity between the perception of rainfall and climate data analysis (Limantol et al., 2016; Etana et al., 2020). However, to buttress this further, the period was divided into two. The trend analysis of rainfall for the first two decades shows about a 58.5-mm decrease in rainfall, while the last two decades reveal about a 24.3-mm decrease in rainfall per decade. This shows that though rainfall has been decreasing, the rate of decrease has slowed in recent years, which concurs with the postulation of rain recovery recently (Sanogo et al., 2015). On the other hand, the temperature steadily increased from the first two decades to the last two decades in the study period, where it rose from 0.08°C to 0.3°C per decade. This is close to the global average, as shown by Hansen et al. (2006).

The perception of the delayed onset of the rainy season is corroborated by the findings of the climate data analysis. It shows that the area has a delay in the onset of the rainy season and the early cessation of the rainy season. Related studies in Nigeria have shown that there is a delay in the onset of the rainy season (Chukwuone, 2015; Nnadi et al., 2019). This corroborates Dunning et al. (2018) that West Africa is experiencing a delay in the onset of the rainy season. Such delays in the onset dates accompanied by early cessation dates affect food security as the possibility of crop failure increases with such variability (Odekunle et al., 2005; Usman and AbdulKadir, 2013). This might result in wilting of plants and likely their death due to insufficient moisture to attain maturity. This portends danger for rain-fed agriculture in the area as it will affect yield (Usman and AbdulKadir, 2013; Shukla et al., 2021). Additionally, the increasing temperature identified by the respondents is validated by the trend analysis of the temperature data and shows that temperature has been rising in the last two decades. The last decade was the hottest across the study period. This is in line with the findings of several studies (Olayemi, 2012; Ndambiri et al., 2012; Chukwuone, 2015; Nnadi et al., 2019). It concurs with the global temperature increase of 0.014°C per year

(Table 2) (Spinage, 2012; Makame and Shackleton, 2019). This is similar to a study by Collins (2011) that there is a 1.5°C increase in African temperature per century.

The climate change and variability in the area are so noticeable that they affect the agribusiness of the area as perceived by the people. This is corroborated by the study by Uguru et al. (2011) that the climate is changing in the area. The most worrisome is the rising temperature, which is highly significant and in line with IPCC's report (IPCC, 2013). Another one is the erratic nature of the rainfall. These are very critical to agricultural production, as there is a maximum tolerable limit of temperature for any crops beyond which they will die. Also, without sufficient moisture available as when due, the crops will wilt and die. This is in line with FAO's (2019) which opines that climate change and variability are the main causes of stress on food production and availability. Hence, the changing climate is a challenge to ensuring food security in the study area and to the achievement of zero hunger of the 2030 agenda for Sustainable Development Goals (SDG).

Conclusion

The analysis of rural farmers' perception of climate change and its relationship with historical climate data was carried out. It shows that the farmers' perception correlates with the results from the analysis of climate data, except for increasing rainfall. This might be due to the ability of human memory to easily recall the most recent event, in which case, there seems to be somehow rain recovery as it rained heavily in 2019. The perception of increasing temperature is upheld by the trend analysis, which showed a significantly increasing trend in the temperature with an average increase of 0.14°C per decade. There is a decrease in annual rainfall of about 8.5 mm per decade in the area. The temperature increase is statistically significant, but the decrease in annual rainfall is not significant. The Tau values of 0.64 for temperature and -0.24 for rainfall indicate that the temperature has a very strong positive relationship with time, unlike rainfall with a moderate negative relation. It shows that there is a higher likelihood for the temperature to rise in the area than the rainfall, which decreases at a lower magnitude. The perception of the farmers that there is a delay in the onset of the rainy season is also corroborated by the trend analysis of the onset dates. This shows that people's perceptions can give reliable information based on their experiences with events happening in their surrounding environment. Such experiences shape their reactions and adaptation strategies, which manifests in their planning for farming activities that affect their food security status.

Hence, the farmers' perceptions and views should be integrated into climate change planning, mitigation, and adaptation policies. Additionally, national policies should also include measures to embark on an aggressive and massive

rural awareness campaign to sensitise the farmers on sound climate change information. The few who responded to the question on the cause of climate change attributed it to the Gods, while others did not answer. Such a knowledge gap will affect how they tackle the menace or their adaptation strategies, as they may likely do nothing since it is God's doing, which nobody can oppose. Knowledge of risk and its causes is key to initiating the right responses and adaptation measures. Therefore, since perception shapes adaptation, the people's indigenous perceptions and experiences should form part of intervention measures and policies for climate change adaptation in the future to command greater participation and wider acceptance. However, studies on perception should always be integrated with quantitative climate data analysis to give more reliable information for decision-making.

Acknowledgments

The authors wish to express their gratitude to the University of Nigeria and Prof. E.U. Madukwe for their support during writing this paper.

References

Abegaz, D.M., & Wims, P. (2015). Extension agents' awareness of climate change in Ethiopia. The *Journal of Agricultural Education and Extension, 21* (5), 479-495.

Adelekan, I.O., & Gbadegesin, A.S. (2005). Analysis of the public perception of climate change issues in an indigenous African city. *International Journal of Environmental Studies*, *62* (1), 115-124.

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic change, 93* (3-4), 335-354.

Adimassu, Z., & Kessler, A. (2016). Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. *Environmental Systems Research, 5* (1), 1-16.

Ahmad, I., Tang, D., Wang, T., Wang, M., & Wagan, B. (2015). Precipitation trends over time using Mann-Kendall and spearman's rho tests in swat river basin, Pakistan. *Advances in Meteorology*, *2015* (2), 1-15.

Alemu, Z.A., & Dioha, M.O. (2020). Climate change and trend analysis of temperature: the case of Addis Ababa, Ethiopia. *Environmental Systems Research*, *9* (1), 1-15.

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management, 16*, 183-194.

Amadou, M.L., Villamor, G.B., Attua, E.M., & Traoré, S.B. (2015). Comparing farmers' perception of climate change and variability with historical climate data in the Upper East Region of Ghana. *Ghana Journal of Geography, 7* (1), 47-74.

Anyadike, R.N.C. (1993). Seasonal and annual rainfall variations over Nigeria. *International Journal of Climatology, 13*, 567-580.

Ayanlade, A., Radeny, M., & Morton, J.F. (2017). Comparing smallholder farmers' perception of climate change with meteorological data: A case study from southwestern Nigeria. *Weather and climate extremes, 15*, 24-33.

Byakatonda, J., Parida, B.P., Kenabatho, P.K., & Moalafhi, D.B., (2019). Prediction of onset and cessation of austral summer rainfall and dry spell frequency analysis in semiarid Botswana. *Theoretical and Applied Climatology, 135* (1), 101-117.

Ceribasi, G., Dogan, E., & Sonmez, O. (2013). Evaluation of Sakarya River streamflow and sediment transport with rainfall using trend analysis. *Fresenius Environmental Bulletin*, *22* (3), 846-852.

Ceribasi, G., Dogan, E., & Sonmez, O. (2014). Evaluation of meteorological and hydrological data of Sapanca basin by trend analysis method. *Journal of Environmental Protection and Ecology, 15* (2), 705-714.

Cherinet, A., & Mekonnen, Z. (2019). Comparing Farmers' Perception of Climate Change and Variability with Historical Climate Data: The Case of Ensaro District, Ethiopia. *International Journal of Environmental Sciences & Natural Resources*, *17* (4), 114-120.

Chukwuone, N. (2015). Analysis of impact of climate change on growth and yield of yam and cassava and adaptation strategies by farmers in Southern Nigeria (No. 12). International Food Policy Research Institute (IFPRI).

Clarke, C.L., Shackleton, S.E., & Powell, M. (2012). Climate change perceptions, drought responses and views on carbon farming amongst commercial livestock and game farmers in the semiarid Great Fish River Valley, Eastern Cape province, South Africa. *African Journal of Range & Forage Science, 29* (1), 13-23.

Collins, J.M. (2011). Temperature variability over Africa. *Journal of Climate*, *24* (14), 3649-3666.

Cuni-Sanchez, A., Omeny, P., Pfeifer, M., Olaka, L., Mamo, M.B., Marchant, R., & Burgess, N.D. (2019). Climate change and pastoralists: perceptions and adaptation in montane Kenya. *Climate and Development, 11* (6), 513-524.

Debela, N., Mohammed, C., Bridle, K., Corkrey, R., & McNeil, D. (2015). Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus*, 4 (1), 1-12.

Del Rio, A., & Brent, M.S. (2014). Agricultural adaptation to climate change in the Sahel: A review of fifteen crops cultivated in the Sahel. *African and Latin American Resilience to Climate Change (ARCC)* United States Agency for International Development by Terra tech ARD.

Dunning, C.M., Black, E., & Allan, R.P. (2018). Later wet seasons with more intense rainfall over Africa under future climate change. *Journal of Climate, 31*, 9719-9738

Enete, A.A., Madu, I.I., Mojekwu, J.C., Onyekuru, A.N., Onwubuya, E.A., & Eze, F. (2011). Indigenous agricultural adaptation to climate change: Study of Imo and Enugu States in Southeast Nigeria. Technology Policy studies Network working paper. Series No. 53

Etana, D., Snelder, D.J., van Wesenbeeck, C.F., & de Cock Buning, T. (2020). Trends of climate change and variability in three agro-ecological settings in central Ethiopia: Contrasts of meteorological data and farmers' perceptions. *Climate, 8* (11), 121.

Ezeh, C.U., Ekwezuo, C., Emeribe, C.N., & Butu, A.W. (2021). Enhanced prediction methods for the onset and cessation dates of the rainy season over the Guinea Savanna, Nigeria. *Arabian Journal of Geosciences*, *14* (3), 1-11.

Falaki, A.A., Akangbe, J.A., & Ayinde, O.E. (2013). Analysis of climate change and rural farmers' perception in North Central Nigeria. *Journal of Human Ecology, 43* (2), 133-140.

FAO (2019). Handbook on Climate Information for farming communities-what farmers need and what is available. Food and Agriculture Organisation of the United Nations, Rome.

Fasoyiro, S.B., & Taiwo, K.A. (2012). Strategies for increasing food production and food security in Nigeria. *Journal of agricultural & food information, 13* (4), 338-355.

Gbetibuo, G.A. (2009). Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa (Vol. 849). Intl Food Policy Res Inst.

Hansen, J., Ruedy, R., Sato, M., & Reynolds, R. (1996). Global surface air temperature in 1995: Return to pre-Pinatubo level. *Geophysical Research Letters*, *23* (13), 1665-1668.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W., & Medina-Elizade, M. (2006). Global temperature change. *Proceedings of the National Academy of Sciences*, *103* (39), 14288-14293.

Hu, Z., Liu, S., Zhong, G., Lin, H., & Zhou, Z. (2020). Modified Mann-Kendall trend test for hydrological time series under the scaling hypothesis and its application. *Hydrological Sciences Journal*, *65* (14), 2419-2438.

Idowu, A.A., Ayoola, S.O., Opele, A.I., & Ikenweiwe, N.B. (2011). Impact of climate change in Nigeria. *Iranica Journal of Energy & Environment*, *2* (2), 145-152.

Ifeanyi-obi, C.C., Togun, A.O., & Lamboll, R. (2016). Influence of climate change on cocoyam production in Aba agricultural zone of Abia State, Nigeria. In Leal Filho (Ed.) *Innovation in Climate Change Adaptation*. (pp. 261-273). Springer, Cham.

Ifeanyi-obi, C.C., & Togun, A.O. (2017). Effects of climate change on cocoyam farming in southeast Nigeria. *International Journal of Social Sciences*, *11* (2), 44-54.

Ifeanyi-Obi, C.C., Togun, A.O., Lamboll, R., Adesope, O.M., & Arokoyu, S.B. (2017). Challenges faced by cocoyam farmers in adapting to climate change in Southeast Nigeria. *Climate Risk Management*, *17,* 155-164.

Ijere, M.O. (1976). Credit infusion as small farmer development strategy: The NTC—Nsukka project. *The Developing Economies, 14* (1), 72-84.

Intergovernmental Panel on Climate Change (IPCC) (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2014). *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects,* Cambridge University Press.

Jarvis, A., Ramirez-Villegas, J., Campo, B.V.H., & Navarro-Racines, C. (2012). Is cassava the answer to African climate change adaptation? *Tropical Plant Biology*, *5* (1), 9-29.

Kaye, J.P., & Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. A review. *Agronomy for sustainable development*, *37* (1), 1-17.

Kendall, M.G. (1975). *Rank correlation methods.* Charles Griffin Book Series. London: Oxford University Press.

Kitzinger, J. (1994). The methodology of focus groups: the importance of interaction between research participants. *Sociology of health & illness*, *16* (1), 103-121.

Laux, P., Jäckel, G., Tingem, R.M., & Kunstmann, H. (2010). Impact of climate change on agricultural productivity under rainfed conditions in Cameroon—A method to improve attainable crop yields by planting date adaptations. *Agricultural and Forest Meteorology, 150* (9), 1258-1271.

Limantol, A.M., Keith, B.E., Azabre, B.A., & Lennartz, B. (2016). Farmers' perception and adaptation practice to climate variability and change: a case study of the Vea catchment in Ghana. *SpringerPlus, 5* (1), 1-38.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., & Hottle, R. (2014). Climate-smart agriculture for food security. *Nature climate change, 4* (12), 1068-1072.

Makame, M. O., & Shackleton, S. (2020). Perceptions of climate variability and change in relation to observed data among two east coast communities in Zanzibar, East Africa. *Climate and Development*, *12* (9), 801-813.

Mann, H.B. (1945). Nonparametric tests against trend. *Econometrica: Journal of the Econometric Society,* 245-259.

Mannack, M. (2009). *How Climate Change threatens Africa's Food Security*. Mail and Guardian Online. South Africa. Online Publishers Associations.

Matiu, M., Ankerst, D.P., & Menzel, A. (2017). Interactions between temperature and drought in global and regional crop yield variability during 1961-2014. *PloS one*, *12* (5), e0178339.

Motiee, H., & McBean, E. (2009). An assessment of long-term trends in hydrologic components and implications for water levels in Lake Superior. *Hydrology Research, 40* (6), 564-579.

Morton, J. (2017). Climate change and African agriculture: unlocking the potential of research and advisory services. In Nunan, F. (Ed.) *Making Climate Compatible Development Happen*. (pp. 87-113). Routledge, London, UK.

National Population Commission-NPC (1991). National Census report. Abuja: Federal Government of Nigeria.

National Population Commission-NPC (2006). National Census Report. Abuja: Federal Government of Nigeria.

Ndambiri, H.K., Ritho, C.N., Mbogo, S.G., Ng'ang'a, S.I., Muiruri, E.J., Nyangweso, P.M., Kipsat, M.J., Ogada, J.O., Omboto, P.I., Kefa, C., & Kubowon, P.C. (2012). Assessment of farmers' adaptation to the effects of climate change in Kenya: the case of Kyuso District. *Journal of Environment and Earth Science, 2*, 74-83.

Nelson, G.C., Valin, H., Sands, R.D., Havlík, P., Ahammad, H., Deryng, D., & Willenbockel, D. (2014). Climate change effects on agriculture: Economic responses to biophysical shocks. *Proceedings of the National Academy of Sciences, 111* (9), 3274-3279.

Nnadi, O.I., Liwenga, E.T., Lyimo, J.G., & Madukwe, M.C. (2019). Impacts of variability and change in rainfall on gender of farmers in Anambra, Southeast Nigeria. *Heliyon, 5* (7), e02085.

Nwamarah, J.U., Olawale, O., Olawale, O.G.T., & Emewulu, C.U.D. (2015). Iodine and nutritional status of primary school children in a Nigerian Community Okpuje, in Nsukka LGA, Enugu State, Nigeria. *Der Pharmacia Lettre, 7* (7), 271-280.

Odekunle, T.O., Balogun, E.E., & Ogunkoya, O.O. (2005). On the Prediction of Rainfall onset and retreat dates in Nigeria. *Theoretical and Applied Climatology, 81,* 101-112.

Ogalleh, S.A., Vogl, C.R., Eitzinger, J., & Hauser, M. (2012). Local perceptions and responses to climate change and variability: The case of Laikipia District, Kenya. *Sustainability, 4* (12), 3302-3325.

Olakojo, S.A., & Onanuga, O.T. (2020). Effects of Climate Change on the Long-run Crops' Yields in Nigeria. *International Journal on Food System Dynamics*, *11* (3), 270-296.

Olayemi, A.O. (2012). Effects of family size on household food security in Osun State, Nigeria. *Asian journal of agriculture and rural development*, *2* (2), 136-141.

Olorunfemi, F. (2010). Risk communication in climate change and adaptation: Policy issues and challenges for Nigeria. http://iopscience.iop.org/1755- 1315.pdf

Onyeneke, R.U., Igberi, C.O., Uwadoka, C.O., & Aligbe, J.O. (2018). Status of climate-smart agriculture in southeast Nigeria. *GeoJournal, 83* (2), 333-346.

Pauw, P. (2013). The role of perception in subsistence farmer adaptation in Africa: Enriching the climate finance debate. *International Journal of Climate Change Strategies and Management, 5* (3), 267-284.

Pohlert, T., Pohlert, M.T., & Kendall, S. (2016). Package 'trend'. Title Non-Parametric Trend Tests and Change-Point Detection. An R package from the Comprehensive R Archive Network (CRAN).

Porter, J.R., Xie, L., Challinor, A.J., Cochrane, K., Howden, S.M., Iqbal, M.M., Lobell, D.B., & Travasso, M.I., (2014). Food security and food production systems. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., & White, L.L. (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Part a: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (pp. 485-533). Cambridge University Press Cambridge, United Kingdom and New York, USA.

Rapholo, M.T., & Makia, L.D. (2020). Are smallholder farmers' perceptions of climate variability supported by climatological evidence? Case study of a semi-arid region in South Africa. *International Journal of Climate Change Strategies and Management 2* (5), 571-585.

Sanfo, S., Lamers, J., Mueller, M., & Fonta, W. (2014). Farmers' Perception of climate change and climate variability versus climatic evidence in Burkina Faso, West Africa. *Proceedings of the Climate Change in Africa. Negotiations, Translations, and Socio-Political Implications* (pp. 1-16), Bonn, Germany.

Sanogo, S., Fink, A.H., Omotosho, J.A., Ba, A., Redl, R., & Ermert, V. (2015). Spatio-temporal characteristics of the recent rainfall recovery in West Africa. *International Journal of Climatology*, *35* (15), 4589-4605.

Shankar, S. (2018). Impacts of Climate Change on Agriculture and Food Security. In Ram Lakhan Singh and Sukanta Mondal (eds) *Biotechnology for Sustainable Agriculture*, (pp. 207-234). Woodhead Publishing.

Shukla, S., Husak, G., Turner, W., Davenport, F., Funk, C., Harrison, L. & Krell, N. (2021). A slow rainy season onset is a reliable harbinger of drought in most food insecure regions in Sub-Saharan Africa. *PLoS ONE 16* (1), e0242883.

Spinage, C.A. (2012). *African ecology: benchmarks and historical perspectives*. Springer Science & Business Media.

Sunday, N.V., & Oghenenyoreme, E.M. (2014). Lithofacies and Paleodepositional Environment of Okpuje and its Environs Nsukka North East Local Government of Enugu State, South Eastern Nigeria. *International Journal of Innovation and Scientific Research, 12* (2), 453-462.

Swanson, K.L., Sugihara, G., & Tsonis, A.A. (2009). Long-term natural variability and 20th century climate change. *Proceedings of the National Academy of Sciences*, *106* (38), 16120-16123.

Sylla, M.B., Elguindi, N., Giorgi, F., & Wisser, D. (2016). Projected robust shift of climate zones over West Africa in response to anthropogenic climate change for the late 21st century. *Climatic Change, 134* (1-2), 241-253.

Teka, O., & Vogt, J. (2010). Social perception of natural risks by local residents in developing countries-The example of the coastal area of Benin. *The Social Science Journal, 47* (1), 215-224.

Tunde, A.M. (2011). Perception of Climate Variability on Agriculture and Food Security by Men and Women Farmers in Idanre LGA, Ondo State. Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *4* (2), 19-32.

Ukonze, J.A. (2012). Impact of Climate Change on Cocoyam Production in South Eastern Nigeria. *International Journal for Education, Science and Public Policy in Africa UESPPA 2* (1), 161-168. Uguru, M.I., Baiyeri, K.P., & Aba, S.C. (2011). Indicators of climate change in the derived savannah Niche of Nsukka, South-Eastern Nigeria. *Agro-Science*, *10* (1-26).

United Nations Development Programme-UNDP (2010). Climate change awareness and adaptation in the Obudu plateau, Cross River State http://aradin.org/modules/AMS/article.php?storyid=11

Usman, M.T., & Abdul, Kadir, A. (2013). On determining the 'real'onset date of seasonal rains in the semi-arid and sub-humid areas of West Africa. *Natural Hazards 66,* 749-758.

Watkiss, P., Pye, S., Hendriksen, G., Maclean, A., Bonjean, M., Shaghude, M., & Khamis, Z. (2012) *The Economics of Climate Change in Zanzibar.* Study Report for the Revolutionary Government of Zanzibar, Climate Change Committee.

Whyte, A.V.T. (1985). Perception. In R. W. Kates, J.H. Ausubel, & M. Berberian (Eds.), *Climate impact assessment: Studies in the interaction of climate and society*. (pp. 403-436). NY: John Wiley and Sons.

Xie, P., & Arkin, P.A. (1997). Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bulletin of the American Meteorological Society, 78*, 2539-2558.

Xie, P., Arkin, P.A., & Janowiak, J.E. (2007). CMAP: The CPC merged analysis of precipitation. In: Levizzani, V., Bauer, P., & Turk, F.J. (Eds.) *Measuring Precipitation from Space.* (pp. 319-328). Springer.

Received: January 17, 2022
Accepted: July 4, 2022

POVEZIVANJE PERCEPCIJE POLJOPRIVREDNIKA O KLIMATSKIM PROMENAMA I VARIJABILNOSTI SA ISTORIJSKIM PODACIMA O KLIMI

Jane O. Ezeh[1], Edith U. Madukwe[1] i Christopher U. Ezeh[2,3]*

[1]Odsek za ishranu i dijetetiku, Poljoprivredni fakultet,
Univerzitet u Nigeriji, Nsukka
[2]Odsek za geografiju, Fakultet društvenih nauka,
Univerzitet u Nigeriji, Nsukka
[3]Centar WASCAL, Univerzitet nauke i
tehnologije Kwame Nkrumah, Kumasi, Gana

R e z i m e

Percepcija poljoprivrednika o klimatskim promenama i varijabilnosti u Okpujeu procenjena je i upoređena sa istorijskim podacima o klimi. Poljoprivrednici uočavaju pojavu promene koja utiče na njihove poljoprivredne aktivnosti, ali im nedostaje naučno razumevanje ove promene. Dok neki ne znaju šta uzrokuje promenu, drugi je pripisuju Božjoj osveti. Percepcije o porastu temperature i odlaganju početka kišne sezone potkrepljene su analizom klimatskih podataka. Temperatura značajno raste i povećavana je za 0,14°C po dekadi između 1960. i 2019. godine. Padavine su se smanjile za 8,5 mm po dekadi. Uočena je tendencija da kišna sezona kasno počinje i rano se završava. Međutim, percepcija povećanih padavina u tom području nije potvrđena analizom trenda zasnovane na podacima o padavinama. Razlika može biti posledica velike varijabilnosti padavina u prostoru i vremenu. Visoke padavine zabeležene u poslednje vreme mogle su predstavljati poteškoće za ljudsko pamćenje jer se bliži događaji pamte lakše nego daleki događaji i stoga se mogu rastumačiti naučnim pristupom. Ipak, s obzirom na to da percepcija oblikuje adaptaciju, iskonske percepcije i iskustva ljudi treba da budu deo interventnih mera i politika za adaptaciju na klimatske promene, kako bi se postiglo veće učešće i šire prihvatanje. Stoga, percepcija poljoprivrednika pruža vitalne informacije, ali bi bila pouzdanija, ako bi se integrisala sa analizom naučnih podataka za donosioce politika i odluka u nauci o klimatskim promenama, što podrazumeva da nijedna od njih ne bi trebalo da bude odbačena, već integrisana.

Ključne reči: klimatske promene i varijabilnost, padavine, temperatura, percepcija, Nigerija.

Primljeno: 17. januara 2022.
Odobreno: 4. jula 2022.

*Autor za kontakt: e-mail: Christopher-uche.ezeh@unn.edu.ng

Journal of Agricultural Sciences (Belgrade) https: https://doi.org/10.2298/JAS2203321S
Vol. 67, No. 3, 2022 UDC: 631.162(497.11)
Pages 321-333 Original scientific paper

THE ASSESSMENT AND RANKING OF THE LIQUIDITY OF SERBIAN AGRICULTURAL ENTERPRISES

Ljubiša Lj. Ševkušić[1], Radomir Ž. Bodiroga[2*] and Veljko P. Vukoje[3]

[1]High school „Petar Kočić“, Vuka Karadžića 77,
75000 Zvornik, Bosnia and Herzegovina
[2]University of East Sarajevo, Faculty of Agriculture,
Vuka Karadžića 30, 71123 Lukavica, Bosnia and Herzegovina
[3]University of Novi Sad, Faculty of Agriculture,
Trg Dositeja Obradovića 8, 21000 Novi Sad, Serbia

Abstract: The key task of all enterprises, regardless of the activity they are engaged in, is constant growth and development. This is a prerequisite for survival in the modern market. The continuous monitoring and analysis of all production and financial performance of the enterprise are extremely important, with liquidity as the most important. It is a very important indicator of the overall financial condition of the company and is the most urgent requirement that is placed before modern companies. Liquidity is defined as the company's ability to timely settle its short-term liabilities. A comprehensive definition of liquidity implies that, in addition to the ability to settle short-term liabilities, the company has enough working capital to continue its current business activity. The focus of this research is on the financial performance of enterprises that, according to the official classification of activities, belong to sector A – Agriculture, forestry and fisheries. The aim of this paper is to evaluate the liquidity of these companies and perform the ranking by applying the modern method of multi-criteria decision-making MABAC. The results of the research clearly show that the liquidity of the agricultural sector of Serbia is not at a satisfactory level, and the best results were recorded in 2019.

Key words: liquidity, agriculture, MABAC method.

Introduction

The Republic of Serbia (RS) has very favorable natural conditions for the development of diverse agricultural production. The key natural resource is high-quality agricultural land that covers an area of 5.097.000 hectares, or 0.54 ha per

*Corresponding author: e-mail: radomir.bodiroga@gmail.com

capita. The share of arable land in total agricultural land is about 82.87%, or calculated per capita – 0.48 ha (Tomaš-Simin, 2019). Although the arable area per capita is higher than in many European countries, research conducted by Vukoje and Miljatović (2018) states that the value of production per hectare in the Republic of Serbia is significantly lower than in agriculturally developed EU countries. The total used agricultural area is dominated by arable land and gardens (74.3%), followed by meadows and pastures (19.2%), while other plantations account for about 5.9%. In terms of the value of agricultural production, plant production is in the lead with about 67.5%, while the share of livestock production is significantly lower, amounting to about 32.5% (Statistical Office of the RS, 2021).

Agriculture, i.e., the entire agri-food sector, has a significant share in the total foreign trade of RS. This is the only sector in the RS economy that has had a positive foreign trade balance for sixteen years. About a fifth of the value of total exports of RS is the export of agri-food products, while this sector participates with about 8% in imports. During 2020, a very significant level of trade in agri-food products was achieved, and the share of these products in the total exports of RS was 21.3%, while in the total imports, the representation of this sector was 8.8% (Ministry of Agriculture, Forestry and Water Management RS, 2022).

These data confirm the great potential of Serbian agriculture and its strategic importance in preserving the stability of the entire economic system. However, there is a significant discrepancy between the business results that enterprises in the field of agriculture achieve and the real potentials they have. Therefore, it is necessary to regularly monitor, analyze and improve all their production and financial performance, with special emphasis on liquidity, which is a very important qualitative indicator of the financial position of the enterprise.

Liquidity is the ability of a company to pay its short-term liabilities on time. For a more complex view of liquidity, in addition to the ability to liquidate short-term liabilities, it is necessary that even after that happens, the company must have sufficient working capital to continue current business activities (Ivanišević, 2012). Liquidity shows the ability of an enterprise to sell or exchange assets for cash in the short term and thus repay its short-term liabilities (Brealey et al., 2007). It is a key determinant of the efficient functioning of each business entity, and at the same time, determines its competitive position in the market (Zimon et al., 2021). Liquidity analysis significantly contributes to the formation of a more complete picture of the financial stability and financial condition of the enterprise. Vukoje (2015) emphasizes that the regular settlement of due liabilities in order to preserve liquidity is a priority task of every enterprise. Therefore, it is necessary to constantly take into account the compliance of the inflow and outflow of money with the maturity of payment obligations. According to Durrah et al. (2016), adequate liquidity management is an important tool, especially for corporate

management, because it reflects the ability of the organization to repay short-term liabilities, which include operating costs and financial costs incurred in the short term.

When evaluating the financial performance of economic entities in recent times, methods of multi-criteria analysis are increasingly used (Eyüboğlu and Çelik, 2016; Mandić et al., 2017; Lukić et al., 2020; Karadag et al., 2022, Lukić 2021; Mimović et al., 2021; Gayathri et al., 2022).

Material and Methods

The analysis included agricultural companies and cooperatives from the RS. The data from the financial statements were used for the six-year time interval (2015–2020), and these data are regularly updated, processed, issued and kept by the Serbian Business Registers Agency (SBRA) 2022. This is a long time span to consider the movement of the most important liquidity indicators of enterprises in the field of agricultural production. The liquidity of RS agricultural enterprises is first analyzed and assessed using a financial balance (short-term and long-term), and then the usual liquidity indicators are used: general (current) liquidity ratio and reduced (accelerated) liquidity ratio.

The general liquidity ratio (GLR) measures the enterprise's ability to settle due liabilities using current assets. It is calculated from the ratio of current assets to current liabilities of the company on the end balance sheet date. The reference value of this indicator is 2 or more than 2 (Rodić et al., 2017). The reduced liquidity ratio estimates the enterprise's liquidity much more strictly and is based on the 1: 1 financing rule. It is calculated by placing the relative ratio of liquid assets (excluding fixed stocks) with short-term liabilities, and the reference value of this indicator needs to be 1 or greater than 1. Thus, this indicator shows the coverage of liabilities by monetary forms of current assets. Given that stocks represent permanently immobilized current assets, it is quite logical that they are excluded from the numerator when calculating this indicator.

In the end, a clearer picture of the liquidity situation and trends was achieved, ranking by years of observation using the MABAC (Multi-Attributive Border Approximation area Comparison) method. The MABAC method is of more recent date and was presented to the scientific public by Pamučar and Ćirović (2015).

Ranking the liquidity indicators of agricultural enterprises in Serbia by years of observation was done/accomplished/performed by MABAC Excel Software, while the results of correlation analysis were obtained using the statistical software SPSS 23.

Results and Discussion

The assessment of the liquidity of agricultural enterprises

Short-term financial balance (STFB) implies that the ratio of liquid and short-term immobilized assets to short-term liabilities is 1:1. The basic preconditions for maintaining liquidity have been met by the enterprise only if this equality exists, or this relationship has been shifted in favor of short-term assets. The research results clearly show that, during the entire observation period (2015–2020), the short-term financial balance of Serbian agricultural enterprises was very unfavorable, i.e., it was significantly shifted in favor of short-term liabilities during the entire observation period (Table 1). The worst value of the coefficient was recorded in 2015 (1.88), and the most favorable was in 2019 (1.63). The reasons for such a bad situation in 2015 should be largely sought in the catastrophic floods that hit a significant part of the territory of Serbia in previous years. The negative effects of this natural disaster were recorded in almost all branches of the economy, especially agriculture, which, by the nature of its activities, directly depends on weather conditions. The total damage was estimated at about 810 million euros, of which the damage to the agricultural sector amounted to about 107.9 million euros or 13.3%. Plant production was particularly affected, which recorded a significant decline in physical volume (about 13.4%) in 2015.

Table 1. Coefficients of short-term and long-term balance.

Years	Coefficients of short-term balance	Coefficients of long-term balance
2015	1.88	0.78
2016	1.76	0.79
2017	1.77	0.83
2018	1.71	0.84
2019	1.63	0.85
2020	1.64	0.85

Source: Authors' calculation based on SBRA data.

In 2020, for every 100 dinars of liquid and short-term tied funds of agricultural companies in Serbia, there was an average of 164 dinars of short-term liabilities. This is a very unfavorable relationship in which companies can theoretically maintain liquidity, provided that the deadlines for payment of short-term liabilities are about 64% longer than the deadlines for collecting short-term receivables. Such deadlines are difficult to achieve in the business practice of domestic agricultural enterprises. There are noticeable variations in the ratio of short-term financial equilibrium, but it is encouraging that its stabilization and

slight improvement are observed, although this is still a fairly high and unfavorable level of this indicator.

Short-term and long-term financial balance (LTFB) are mutually conditioned, i.e., if there is a short-term balance, then there is a long-term, and vice versa. The analysis of long-term financial balance is based on the comparison of long-term tied funds with permanent and long-term sources of financing. Taking into account the presented unfavorable state of short-term financial balance, it is logical that the long-term financial balance should be shifted towards long-term tied assets. This is confirmed by the presented coefficients of long-term financial balance in all years of the analyzed period.

For the analysis and consideration of the long-term financial balance, it is very important to look at its situation from the aspect of net working capital. Net working capital (NWC) is a segment of long-term liabilities and equity that serves to finance current assets. The state of long-term financial balance is checked by comparing the net working capital with fixed stocks. Financial balance and basic preconditions for maintaining liquidity exist only if the net working capital is equal to constant stocks. Favorable situation and security in maintaining liquidity occur if the net working capital is greater than fixed stocks. If the net working capital is less than fixed stocks, it is indicative that there are liquidity problems. Finally, if the NWC is negative, it means that there is a drastic disturbance of the financial balance, i.e., the structure.

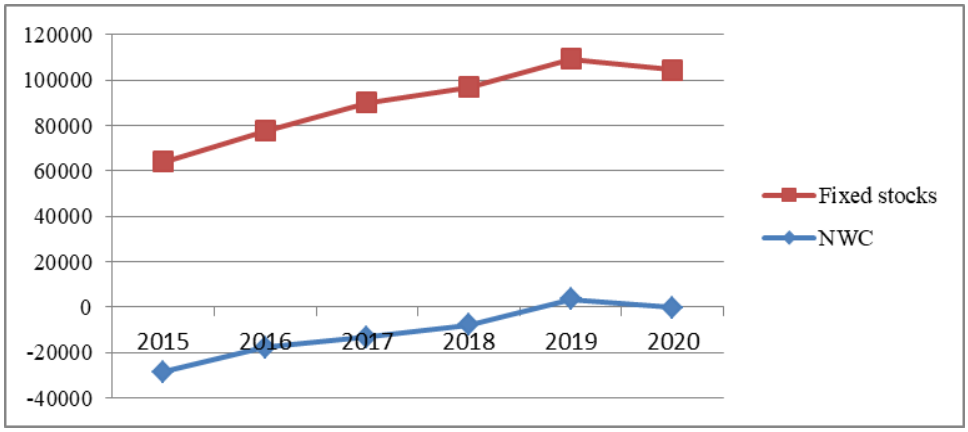

Figure 1. The dynamics of NWC and fixed stocks of agricultural enterprises.

The results of the analysis of the financial balance based on the working capital (Figure 2) indicate a very unfavorable financial structure of enterprises in the agricultural sector of Serbia. NWC was negative in almost all years of the observed six-year period (except in 2019), meaning there is no talk of the existence

of financial balance, ie. preconditions for establishing liquidity. In these conditions, in addition to fixed stocks as a whole, a good part of fixed assets is financed from short-term liabilities. In order to establish long-term financial balance, enterprises in the field of agricultural production in 2020 lack about 892 million euros of long-term sources of financing.

The presented indicators of general and reduced liquidity (Figure 3) also confirm that agricultural companies in Serbia are facing a serious problem of illiquidity, i.e., the inability to settle due obligations in a timely manner. The values of the obtained general and reduced liquidity ratios for the entire observed period deviate significantly from the reference values.

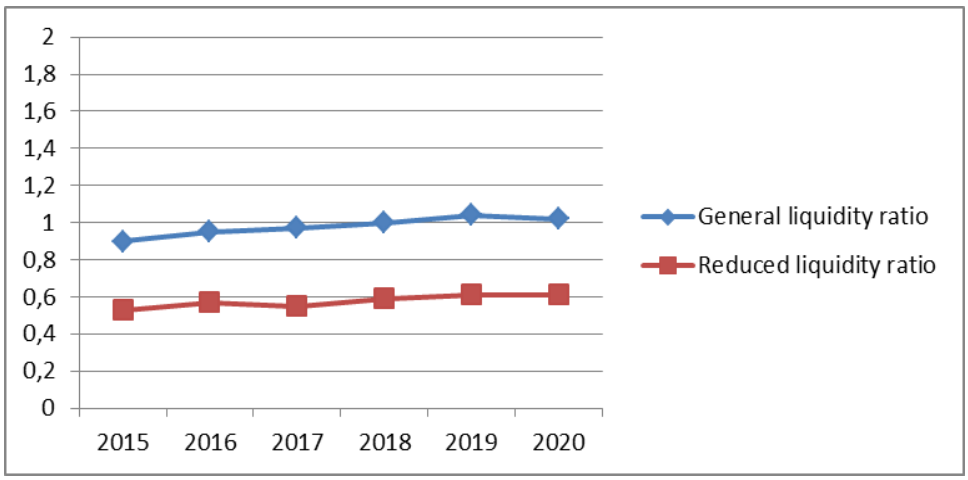

Figure 2. The movement of general and reduced liquidity ratios.

Liquidity ranking of agricultural enterprises

When ranking the liquidity of agricultural enterprises of the Republic of Serbia on the basis of the MABAC method, previously calculated and presented liquidity indicators were used as criteria: C1-short-term financial balance, C2-long-term financial balance, C3-general liquidity ratio and C4-net working capital. The years of observation were taken as alternatives: A1-2015, A2-2016, A3-2017, A4-2018, A5-2019 and A6-2020.

With the help of correlation analysis, it is necessary to determine whether one of the criteria is in conflict with another, i.e., the degree of their connection is determined. The results of the correlation analysis (Pearson's correlation coefficient) show a high degree of correlation between the selected liquidity criteria (Table 2).

Table 2. Correlation analysis.

		STFB	LTFB	NWC	GLR
STFB	Correlation	1	-.881	-.984	-.980
	Sig.		.021	.000	.001
LTFB	Correlation	-.881	1	.936	.943
	Sig.	.021		.006	.005
NWC	Correlation	-.984	.936	1	.996
	Sig.	.000	.006		.000
GLR	Correlation	-.980	.943	.996	1
	Sig.	.001	.005	.000	

Source: Authors' calculation using SPSS.

In order to rank the alternatives, it is necessary to define the weighting coefficients for each criterion (Table 3), i.e., to determine the importance of each criterion in relation to other criteria. Puška (2011) states that weighting coefficients are usually numbers that are subjectively chosen, i.e., they reflect the subjective preferences of analysts based on relative knowledge of the mutual meaning of criteria, and the sum of these numbers should be equal to one. He further points out that the weighting coefficients are one of the central places of multicriteria analysis because the results obtained by different methods depend on their values. The weighting coefficients for the purposes of this paper were calculated by the AHP (Analytical Hierarchical Process) method (Saaty, 2008).

Table 3. The weight coefficients of the criteria.

Criterion	Weights of criteria
STFB	0.125
LTFB	0.375
GLR	0.125
NWC	0.375
SUM	1.00

Source: Authors' calculation.

The first step in applying the multi-criteria decision-making method was to define the initial decision-making matrix (Table 4).

Table 4. The initial matrix.

weights of criteria	0.125	0.375	0.125	0.375
kind of criteria	1	1	1	1
	C1	C2	C3	C4
A1	1.88	0.78	0.9	-28505.85
A2	1.76	0.79	0.95	-17828.37
A3	1.77	0.83	0.97	-13321.49
A4	1.71	0.84	1	-7936.39
A5	1.63	0.85	1.04	3490.82
A6	1.64	0.85	1.02	-361.49
MAX	1.88	0.85	1.04	3490.82
MIN	1.63	0.78	0.9	-28505.85

Source: Authors' calculation.

The second step was the normalization of the elements of the initial matrix (Table 5).

Table 5. The normalized matrix.

weights of criteria	0.125	0.375	0.125	0.375
kind of criteria	1	1	1	1
	C1	C2	C3	C4
A1	1.0000	0.0000	0.0000	0.0000
A2	0.5200	0.1429	0.3571	0.0000
A3	0.5600	0.7143	0.5000	0.0000
A4	0.3200	0.8571	0.7143	0.0000
A5	0.0000	1.0000	1.0000	1.0000
A6	0.0400	1.0000	0.8571	0.0000

Source: Authors' calculation.

The third step was the calculation of the weighted matrix (Table 6).

Table 6. The normalized weighted matrix.

	C1	C2	C3	C4
A1	0.2500	0.3750	0.1250	0.3750
A2	0.1900	0.4286	0.1696	0.3750
A3	0.1950	0.6429	0.1875	0.3750
A4	0.1650	0.6964	0.2143	0.3750
A5	0.1250	0.7500	0.2500	0.7500
A6	0.1300	0.7500	0.2321	0.3750

Source: Authors' calculation.

The fourth step in applying the MABAC method was determining the border approximation area (Table 7).

Table 7. The border approximation area matrix.

	C1	C2	C3	C4
g_i	0.1708	0.5860	0.1916	0.4209

Source: Authors' calculation.

The fifth step involved calculating the elements of the matrix of distances of the alternatives from the border approximation area (Table 8).

Table 8. The distance of alternatives from the border approximation area matrix.

	C1	C2	C3	C4
A1	0.0792	-0.2110	-0.0666	-0.0459
A2	0.0192	-0.1574	-0.0219	-0.0459
A3	0.0242	0.0569	-0.0041	-0.0459
A4	-0.0058	0.1105	0.0227	-0.0459
A5	-0.0458	0.1640	0.0584	0.3291
A6	-0.0408	0.1640	0.0406	-0.0459

Source: Authors' calculation.

In the last step, all alternatives included in the research were ranked from the most favorable to the most unfavorable (Table 9). The best ranked alternative is the one whose relative distance value is closest to one, while other alternatives are ranked in descending order.

Table 9. The ranking of alternatives.

Alternatives	Q	Q	Ranking
A1	-0.2443	-0.2443	6
A2	-0.2061	-0.2061	5
A3	0.0311	0.0311	4
A4	0.0814	0.0814	3
A5	0.5057	0.5057	1
A6	0.1179	0.1179	2

Source: Authors' calculation.

The obtained results of the empirical research of ranking enterprises in the field of agricultural production in Serbia using the MABAC method clearly show that 2019 was the most successful year in terms of their liquidity. A significant growth in the foreign trade of agri-food products, with maximum values in the past decade in almost all segments, produced, for the most part, such good results in 2019. It is subsequently followed by 2020, 2018, 2017, 2016 and 2015. It encouraged some improvement in the liquidity of agricultural enterprises in the last three years of the analyzed period.

The main reason for the improvement of liquidity indicators of agricultural enterprises in the RS lies in the fact that there was an increase in current assets (2.79%), within which the largest increase was recorded in trade receivables (4.47%) and cash of as much as 14.03%, as the most liquid form of current assets. At the same time, there was a decline in short-term liabilities of 1.71%. Simultaneously the decrease in the value of short-term financial investments suggests a redistribution of investments in non-monetary forms of current assets, which requiring special attention to, since it is a highly liquid form of assets (Zajmi, 2021). Lukić et al. (2021) state that the improvement of the efficiency of Serbian agricultural enterprises in recent years has been positively influenced by numerous macro and micro factors: improvement of general economic conditions, lower interest rates, higher subsidies and grants, regulation of farmers' labor markets, the increased placement of agricultural products in foreign markets, a greater understanding of the importance of ensuring agricultural production from adverse climate change, a better collection of receivables, as well as the application of modern technology in agriculture.

Conclusion

Based on the obtained results of empirical research for the observed time distance with the application of the MABAC method of multi-criteria decision-making, it was determined that the agricultural companies of Serbia were the most liquid in 2019. It was subsequently followed by 2020, 2018, 2017, 2016 and 2015 (table 9). There has been a slight improvement in the liquidity of agricultural enterprises during the last three years of the observed period, although the obtained values of the indicators indicate that enterprises in this sector continue to face a serious problem of illiquidity. Given that the research is based on accumulated data, there is no doubt that a good part of RS agricultural companies has problems with illiquidity. Of course, some enterprises do not have these problems, i.e., they effectively manage their liquidity. We should not ignore the fact that liquidity indicators obtained by confronting balance sheet positions on the balance sheet date due to their staticity in industries with seasonal business characteristics, such as agriculture, have limited analytical values.

In order to improve liquidity, as well as other financial indicators of Serbian agricultural enterprises, greater support is needed from state bodies and other competent institutions in the field of subsidies, breaking the monopolies of processors and traders, more favorable lending and more stimulating tax policy. Also, the establishment of futures trade would contribute to the creation of risk and return control opportunities in the market of agricultural products.

In general, traditional methods of financial analysis lead to the same conclusions as the MABAC method, with the main advantage of this method being the ability to rank different alternatives even in situations where individual financial indicators do not give a clear picture about it, which is a very common case in modern business.

Finally, it is clear that modern multi-criteria decision-making methods are very useful tools, especially for company management to obtain a more comprehensive view of liquidity and other financial performance indicators, because they significantly contribute to making the right business decisions.

References

Brealey, R., Myers, S., & Marcus, A. (2007). *Fundamentals of Corporate Finance*, 5th Edition, New York: McGraw- Hill Book Company.

Durrah, O., Rahman, A.A., Jamil, S., & Ghafeer, N.A. (2016). Exploring the Relationship between Liquidity Ratios and Indicators of Financial Performance: an Analytical Study on Food Industrial Companies Listed in Amman Bursa. *International Journal of Economics and Financial Issues, 6,* 435-441.

Eyüboğlu, K., & Çelik, P. (2016). Financial Performance Evaluation of Turkish Energy Companies with Fuzzy AHP and Fuzzy TOPSIS Methods. *Business and Economics Research Journal, 7,* 21-37.

Gayathri, C., Kamala, V., Gajanand, M., & Yamini, S. (2022). Analysis of operational and financial performance of ports: an integrated fuzzy DEMATEL-TOPSIS approach. *Benchmarking: An International Journal, 29* (3), 1046-1066.

Ivanišević, M. (2012). *Poslovne finansije*. Beograd: Centar za izdavačku delatnost Ekonomskog fakulteta.

Karadağ Ak, Ö., Hazar, A., & Babuşcu, Ş. (2022). Evaluation of the financial performance of development and investment banks with entropy-based ARAS method. *Macroeconomics and Finance in Emerging Market Economies*, 1-21.

Lukić, R., Vojteski, Kljenak, D., & Anđelić, S. (2020). Analyzing financial performances and efficiency of the retail food in Serbia by using the AHP-TOPSIS method. *Economic of Agriculture, 67*, 55-68.

Lukić, R. (2021). Application of MABAC Method in Evaluation of Sector Efficiency in Serbia. *Review of International Comparative Management, 22* (3), 400-418.

Lukić, R., Vojteski-Kljenak, D., Anđelić, S., & Gavrilović, M. (2021). Application of WASPAS method in the evaluation of efficiency of agricultural enterprises in Serbia. *Economics of Agriculture, 68*, 375-388.

Mandić, K., Delibašić, B., Knežević, S., & Benković, S. (2017). Analysis of the efficiency of insurance companies in Serbia using the fuzzy AHP and TOPSIS method. *Economic Research, 30,* 550-565.

Mimović, P., Tadić, D., Borota-Tišma, D., Nestić, S., & Lafuente, J. (2021). Evaluation and ranking of insurance companies by combing TOPSIS and interval fuzzy rough sets. *Serbian Journal of Management, 16*, 279-299.

Ministry of Agriculture, Forestry and Water Economy of the Republic of Serbia. Report on the situation in Agriculture RS. Retrieved from: http://www.minpolj.gov.rs/ (January 16, 2022).

Pamučar, D., & Ćirović, G. (2015). The selection of transport and handling resources in logistics centres using Multi-Atrtibutive Border Approximation area Comparison (MABAC). *Expert Systems with Applications, 42*, 3016-3028.

Puška, A. (2011). Rangiranje investicionih projekata pomoću modifikovane AHP metode. *Tranzicija, 13*, 125-136.

Rodić, J., Andrić, M., Vukelić, G., & Vuković, B. (2017). *Analiza finansijskih izveštaja*. Novi Sad: Ekonomski fakultet.

Saaty, T. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences, 1*, 83-98.

Serbian Business Registers Agency. Financial statements annual bulletin. Retrieved from: https://www.apr.gov.rs/ (February 05, 2022).

Statistical Office of the Republic of Serbia. Statistical Yearbook 2021. Retrieved from: https://www.stat.gov.rs/. (February 10, 2022).

Tomaš-Simin, M. (2019). *Ekonomski efekti organske proizvodnje u poljoprivredi Republike Srbije,* Univerzitet u Novom Sadu.

Vukoje, V. (2015). *Finansijski položaj preduzeća iz oblasti poljoprivrede i prehrambene industrije Vojvodine,* Poljoprivredni fakultet, Novi Sad.

Vukoje, V., & Miljatović, A. (2018). *Rezultati poslovanja privrednih subjekata iz oblasti poljoprivrede i prehrambene industrije Vojvodine,* Poljoprivredni fakultet, Novi Sad.

Zimon, G., Nakonieczny, J., Chudy-Laskowska, K., & Wójcik-Jurkiewicz, Kochański, K. (2021). An Analysis of the Financial Liquidity Management Strategy in Construction Companies Operating in the Podkarpackie Province. *Risks*, MDPI, 10, 1-15.

Zajmi, S. (2021). Analiza likvidnosti i solventnosti realnog sektora privrede Srbije. *Economy and Market Communication Review, 11*, 294-306.

Received: March 31, 2022
Accepted: August 24, 2022

OCENA I RANGIRANJE LIKVIDNOSTI POLJOPRIVREDNIH PREDUZEĆA SRBIJE

Ljubiša Lj. Ševkušić[1], Radomir Ž. Bodiroga[2*] i Veljko P. Vukoje[3]

[1]Srednja škola„Petar Kočić“, Vuka Karadžića 77,
75000 Zvornik, Bosna i Hercegovina
[2]Univerzitet u Istočnom Sarajevu, Poljoprivredni fakultet,
Vuka Karadžića 30, 71123 Lukavica, Bosna i Hercegovina
[3]Univerzitet u Novom Sadu, Poljoprivredni fakultet,
Trg Dositeja Obradovića 8, 21000 Novi Sad, Srbija

R e z i m e

Ključni zadatak svih preduzeća, bez obzira na delatnost kojom se bave, jeste stalan rast i razvoj. To je preduslov za opstanak na savremenom tržištu. Izuzetno je važno kontinuirano praćenje i analiza svih proizvodnih i finansijskih performansi preduzeća, pri čemu je likvidnost među najvažnijima. To je veoma važan pokazatelj ukupnog finansijskog stanja preduzeća i najhitniji je zahtev koji se postavlja pred savremena preduzeća. Likvidnost se definiše kao sposobnost preduzeća da blagovremeno izmiruje svoje kratkoročne obaveze. Sveobuhvatna definicija likvidnosti podrazumeva da, pored mogućnosti izmirenja kratkoročnih obaveza, preduzeće ima dovoljno obrtnih sredstava za nastavak tekuće poslovne aktivnosti. Fokus ovog istraživanja je na finansijskim rezultatima preduzeća koja, prema zvaničnoj klasifikaciji delatnosti, pripadaju sektoru A – Poljoprivreda, šumarstvo i ribarstvo. Cilj ovog rada je da se proceni likvidnost ovih preduzeća i izvrši rangiranje primenom savremenog metoda višekriterijumskog odlučivanja MABAC. Rezultati istraživanja jasno pokazuju da likvidnost poljoprivrednog sektora Srbije nije na zadovoljavajućem nivou, a najbolji rezultati su zabeleženi u 2019. godini.

Ključne reči: likvidnost, poljoprivreda, MABAC metoda.

Primljeno: 31. marta 2022.
Odobreno: 24. avgusta 2022.

[*]Autor za kontakt: e-mail: radomir.bodiroga@gmail.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