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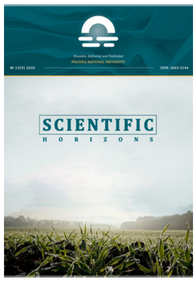

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The effect of humic growth stimulants on the productivity of chickpea (*Cicer arietinum* L.) varieties

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Abstract. In organic farming, the use of plant growth biostimulants in crop cultivation technologies, including chickpea, has become widespread. The purpose of this study: to investigate the manifestation of productivity elements and the yield of chickpea varieties depending on the treatment with an organic growth stimulator. The study employed the following methods: field – to determine the level of yield, laboratory – to investigate the elements of productivity of chickpea, and statistical – to assess

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the reliability of experimental studies. By treatment options, the complex application of the product during pre-sowing seed treatment and foliar feeding of plants during the growing season was distinguished. The effect of organic growth stimulant on the increase of productivity elements of chickpea in this variant of the experiment was noted by an average of 10.0%. The greatest effect of the preparation was found in the complex treatment of seeds and plants of common chickpea in terms of seed weight per plant (24.0%). They were identified by the influence of varietal properties on the productivity elements of common chickpea varieties Triumf and Pamiat. The Pamiat variety with the seed treatment + foliar dressing variant was the best in terms of chickpea yield, but the Triumf variety had the greatest effect of the growth stimulator on the yield increase. Close correlations were found between seed weight per plant and thousand-kernel weight, number of beans per plant and number of seeds per plant, and yield with plant productivity and thousand-kernel weight. The findings of the study are recommended to be used to adjust the elements of chickpea cultivation technology to increase productivity in production conditions

Keywords: seed treatment; foliar feeding; yield; productivity elements

INTRODUCTION

The increase in the cost of mineral fertilisers and plant protection products has led to the search for other sources of nutrients, using natural and synthetic growth regulators that are safer for the environment, which allows for greater use of the biological potential of the crop. O.I. Tsyliuryk (2019) and O.I. Tsyliuryk *et al.* (2022) argue that to optimise plant productivity, it is necessary to use new generation biological plant growth stimulants that accelerate growth processes, increase adaptive capacity, and increase the productive potential of the crop as a whole.

To improve the efficiency of breeding work, Ukrainian scientists have developed variety models for each soil and climatic zone, as highly productive samples in one zone do not always have positive results in other growing zones. Therefore, O.V. Tryhub *et al.* (2020) recommend developing a series of crops for each soil and climatic zone. M.O. Kolesnikov and T.R. Kadyrov (2022) highlight well-known Ukrainian chickpea breeders who have created varieties of chickpea with high adaptive capacity, drought resistance, suitability for mechanised harvesting and disease resistance, as well as a yield potential of 2-3 t/ha.

M.I. Kondratenko *et al.* (2020) address the model of the chickpea variety of the Selection and Genetic Institute, which makes provision for the selection of such indicators as small leaves, compressed bush, tall height of the lower bean, thousand-kernel weight over 400 g and, accordingly, a high yield. D.D. Verma *et al.* (2020) recommend using a model with a high cultivar technology: the height of the lower bean is above 25 cm; the plant height is 50-65 cm to obtain a high yield.

N.O. Vus and L.N. Kobyzieva (2018) highlight the indicators of the large number of beans per plant and seed size. However, chickpea varieties with a large seed weight are demanding on growing conditions, and therefore their resistance to adverse environmental factors must be considered. According to their research, it was found that two varieties of chickpea of the kabuli type combine about seven economically valuable traits. The Ukrainian variety Rosanna is characterised by high levels of drought resistance, ascochyta leaf blight resistance, productivity, thousand-kernel weight, boiling rate, protein content, and a positive reaction to nitraginisation. A sample of Azerbaijani origin was selected for the following traits: drought resistance, resistance to ascochyta leaf blight, seeds per plant, yield level, and cooking property.

O.O. Khodanitska *et al.* (2021) argue that the use of growth stimulants increases the yield of field crops, including chickpeas. There are preparations of natural origin. The use of plant growth stimulants provides a yield increase of up to 20%. These researchers found that to activate the germination of legume seeds, this group of preparations is used by means of pre-sowing seed treatment. The number of sprouted seeds under the treatment with growth stimulants was higher by 3-5 pcs. in bean samples compared to the control. D. Kaur and P. Singh (2020) investigated the impact of biological products on increasing crop yields, which is effective from both an environmental and economic standpoint. According to their findings, chickpea samples with seed inoculation exceeded the control samples by 15.3-15.5% in terms of yield. The researchers confirm the effectiveness of using new generation growth regulators to increase agricultural production.

I.V. Nepran *et al.* (2021) found that pre-sowing treatment showed a positive effect of growth stimulants on pea productivity. According to the findings of the cited study, pre-sowing treatment of pea seeds with Emistim C increased the intensity of both growth processes and plant height by 1.1-1.2 cm per day. The use of humic preparations in studies with sowing samples contributed to an increase in yield compared to the control. An increase in the yield of spring vetch by 10-15% was found with the use of Triman and Humisol growth stimulants. Many studies have confirmed that high-quality seed is the key to high yields of field crops. A.V. Bahan *et al.* (2020) note the significance of foliar feeding of plants as the most common measure of plant protection against pests. At the same time, the findings of their study revealed an increase in the elements of seed productivity of chickpea by 3.6-17.5% in the variant of seed inoculation with Biomag chickpea preparation compared to the control.

S.O. Yurchenko *et al.* (2021) state that the use of the humic preparation 1R Seed treatment resulted in an increase in field germination of peanut varieties by 7.5-18.3%. Under the influence of this preparation on the duration of the interphase period "sowing-sprouting", it was found to be reduced by 3-5 days compared to the control. The effectiveness of the 1R Seed treatment growth stimulant contributed to the friendly germination and healthy plants.

The effectiveness of plant growth stimulants is influenced by a series of factors, including variety properties, methods and timing of application, and growing conditions. Therefore, the study of the impact of this group of products on plant productivity in a particular climate zone is a relevant task. The purpose of this study was to investigate the effect of growth stimulant on the processes of productivity formation of chickpea in the Central Forest-Steppe of Ukraine.

MATERIALS AND METHODS

The study was conducted in 2021-2023 in the Central Forest-Steppe of Ukraine (Poltava region). The research material was four varieties of common chickpea from the Breeding and Genetic Institute of the National Centre for Seed Science and Variety Studies of the National Academy of Agrarian Sciences of Ukraine: Budzhak, Triumf, Pamiat, Odysei. The research design included the following variants: control (no treatment); seed treatment; foliar dressing; seed treatment + foliar dressing. Seed treatment and foliar dressing were performed with an organic growth stimulant of humic origin from Soil-Biotics (USA) – Foliar Concentrate. The seeds were treated before sowing with this product at a rate of 0.6 kg/t. The plants were fertilised in the budding phase at a rate of 2.0 kg/ha. The climate of this region is temperate continental with high temperatures and unevenly distributed precipitation during the spring and summer. The amount of precipitation during the year is 450-550 mm. The soils are typical chernozems, characterised by intensive accumulation of humus and nutrients, medium-grained structure, and shallow carbonates. The humus content in the topsoil is 3.8-4.3%.

During the study, winter wheat was the predecessor. Sowing was performed in the optimal time for the crop – the first decade of April. The sowing method is conventional row sowing with a row spacing of 15 cm. The registered area of the plot was 25 m^2. The replication was fourfold. The location of the plots in the experiment was systematic. The technology of chickpea cultivation was generally accepted and did not differ by experimental variants, except for the type of treatment with the growth stimulator Foliar Concentrate.

During the experiment, the following research methods were employed: field – to determine the level of chickpea yield by experimental variants; laboratory – to determine the elements of productivity of chickpea plants by the factors under study; statistical – to determine the least significant difference (LSD_{05}) according to the method of analysis of variance and to establish the relationship between the elements of productivity, and the level of chickpea yield according to the method of correlation and regression analysis. The research variants were studied according to the following indicators: plant height (cm), beans per plant (pcs.), seeds per plant (pcs.), seeds per bean (pcs.), weight of seeds per plant (g), thousand-kernel weight (g), and yield (t/ha). The level of yield of chickpea by experimental variants was determined according to the method of continuous accounting. The data obtained from the laboratory and field studies was analysed using the statistical analysis package "Statistica 12.0" (Yeshchenko *et al.*, 2014).

The weather conditions during the surveys had minor deviations compared to the long-term average. In terms of moisture and temperature conditions, favourable conditions for chickpea cultivation during the growing season were in 2022, which provided satisfactory conditions for the formation of high productivity. Worse weather conditions were observed in 2023 due to insufficient precipitation in the second half of the growing season. Experimental plant research, including the collection of plant material, was in line with institutional, national, and international guidelines: The Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS

According to the research results, the level of manifestation of productivity elements of chickpea by the variants of the experiment was determined (Table 1).

Table 1. *Productivity elements of chickpea (Cicer arietinum L.) (average for 2021-2023)*

Variety (factor A)	Treatment variant (factor B)	BP, cm	CBD, pcs.	SPB, pcs.	SPP, pcs.	SWP, g	TKW, g
Budzhak	control	59.0	52.0	1.08	56.2	16.5	276.0
	seed treatment	63.1	56.3	1.12	63.1	17.5	281.8
	foliar dressing	66.0	58.7	1.16	68.1	18.8	286.2
	seed treatment + foliar dressing	68.1	59.6	1.18	70.3	19.3	290.8

Table 1. Continued

Variety (factor A)	Treatment variant (factor B)	BP, cm	CBD, pcs.	SPB, pcs.	SPP, pcs.	SWP, g	TKW, g
Triumf	control	72.2	61.0	1.12	68.3	16.1	252.1
	seed treatment	76.3	63.8	1.18	75.3	17.0	258.5
	foliar dressing	78.3	65.6	1.23	80.7	18.1	264.0
	seed treatment + foliar dressing	81.1	67.3	1.25	84.1	18.9	268.7
Pamiat	control	71.7	55.3	1.07	59.2	18.3	322.4
	seed treatment	75.7	58.5	1.13	66.1	19.2	329.8
	foliar dressing	79.8	60.2	1.17	70.4	20.5	337.2
	seed treatment + foliar dressing	81.6	61.0	1.20	73.2	21.3	342.0
Odysei	control	56.5	59.0	1.03	60.8	16.8	283.2
	seed treatment	59.8	62.3	1.07	66.7	18.0	289.8
	foliar dressing	61.5	65.6	1.12	73.5	19.2	295.4
	seed treatment + foliar dressing	63.6	66.2	1.14	75.5	20.0	299.7
mean		*69.6*	*60.8*	*1.14*	*69.5*	*18.5*	*292.4*

Notes: *PH – plant height, BPP – beans per plant, SPB – seeds per bean, SPP – seeds per plant, SWP – seed weight per plant, TKW – thousand-kernel weight*
Source: *compiled by the authors of this study*

According to the average data, the lowest value for the studied indicators was found in the control variant, and the highest – in the variant of seed treatment + foliar feeding, which indicates the effectiveness of the growth stimulator Foliar Concentrate during the complex treatment of seeds and plants. The height of the plant varied within 56.5-81.6 cm according to the experimental variants. Treatment of undersized chickpea varieties Budzhak and Odysei with the preparation according to the variant of seed treatment + foliar dressing, compared to the control, increased the plant height by 9.1 cm and 7.1 cm, respectively. In the taller varieties Triumf and Pamiat, this figure increased by 8.9 cm and 9.8 cm, respectively.

The number of beans per plant was within 52.0-67.3 pieces. On average, this indicator increased by 6.7 units in the experiment when using the growth stimulator in the variant of seed treatment + foliar dressing. The largest number of beans per plant was observed in the Triumph variety – 67.3 pieces. The number of seeds per bean, as a varietal trait, varied within insignificant limits and was equal to 1.03-1.25 pieces. Complex treatment with the product helped to increase this indicator by an average of 0.12 pieces. The Triumf chickpea variety had the highest number of seeds per bean – 1.25 pieces. The number of seeds per plant depends on the number of seeds in the bean, which was 56.2-84.1 seeds, respectively. In the variant of seed treatment + foliar feeding, the number of seeds per plant increased by 12.1 pieces on average. The Triumf chickpea variety was also distinguished by this indicator (84.1 pcs).

The seed weight per plant varied within 16.1-21.3 g. Integrated processing contributed to an average increase of 2.9 g. The highest plant productivity was observed in the Pamiat chickpea variety – 21.3 g. The thousand-kernel weight in the experimental variants was 252.1-342.0 g, respectively. The use of this preparation in the variant of seed treatment + foliar dressing allowed increasing the indicator under study by an average of 16.8 g. The largest thousand-kernel weight was that of the Pamiat chickpea variety – 342.0 g. Figure 1 shows the effect of growth stimulant on the level of manifestation of productivity elements of chickpea by treatment variants compared to the control.

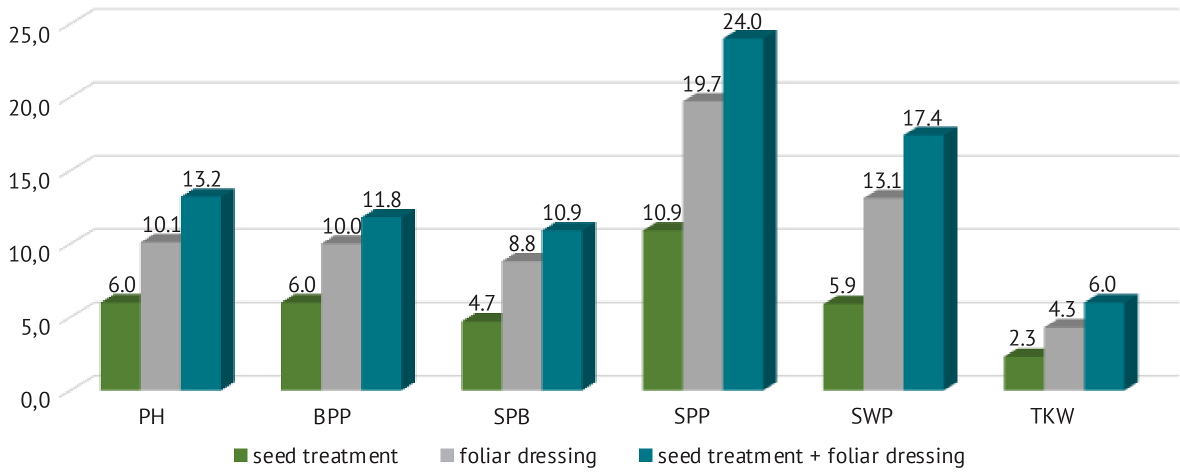


Figure 1. *Effect of the preparation on the increase of chickpea productivity elements by treatment variants compared to the control, %*

Note: *PH – plant height, BPP – beans per plant, SPB – seeds per bean, SPP – seeds per plant, SWP – seed weight per plant, TKW – thousand-kernel weight*

Source: *compiled by the authors of this study*

According to Figure 1, the test preparation influenced the increase in the studied parameters as follows: plant height – by 6.0-13.2%, beans per plant – by 6.0-11.8%, seeds per bean – by 4.7-10.9%, seeds per plant – by 10.9-24.0%, weight of seeds per plant – by 5.9-17.4%, thousand-kernel weight – by 2.3-6.0%. The complex treatment with a growth stimulator increased the manifestation of all parameters under study, except for the thousand-kernel weight, by more than 10.0%. The index of seed weight per plant in this variant of the experiment increased by 24.0%. This suggests the effect of this product on plant height and fruit and seed formation during the growing season. According to the results of the correlation analysis, a strong correlation was found between the following indicators: thousand-kernel weight and weight of seeds per chickpea plant (r = 0.77), as well as the number of beans per plant and the number of seeds per chickpea plant (r = 0.91) (Fig. 2).

According to Figure 2, the effect of the growth stimulant on increasing the water content of chickpea plants per plant and increasing productivity per plant was noted. Yields varied slightly over the years of research: 2021 – 0.98-2.43 t/ha, 2022 – 1.17-2.57 t/ha, 2023 – 0.82-2.09 t/ha. The highest level of chickpea yields was recorded in 2022 (Table 2).

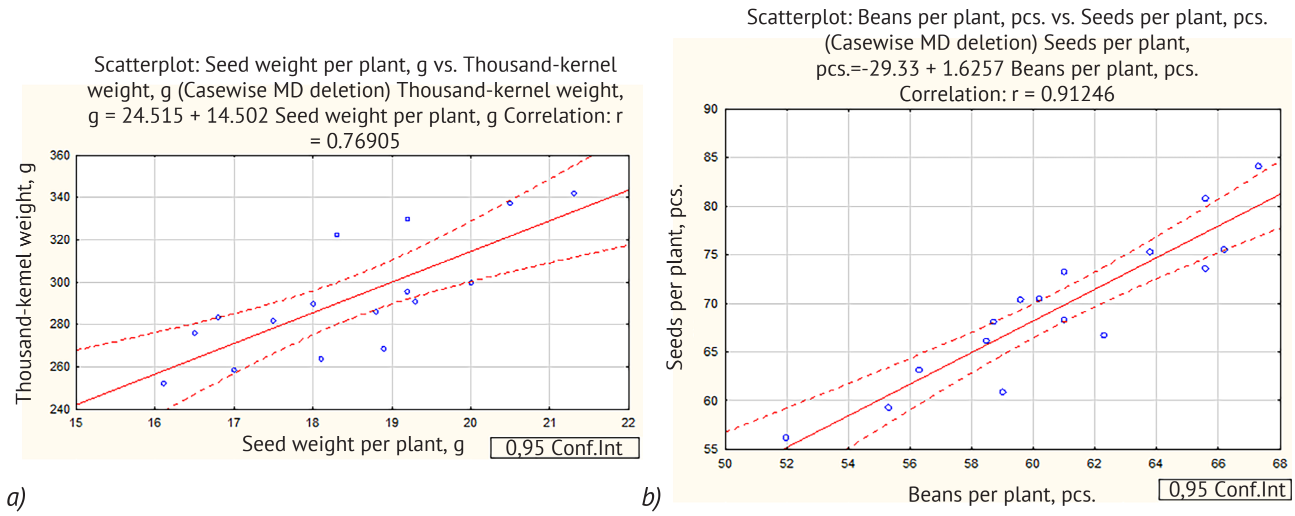


Figure 2. *Correlation of productivity elements of chickpea*

Note: *a) correlation between thousand-kernel weight and weight of seeds per plant; b) correlation between number of beans per plant and number of seeds per plant*

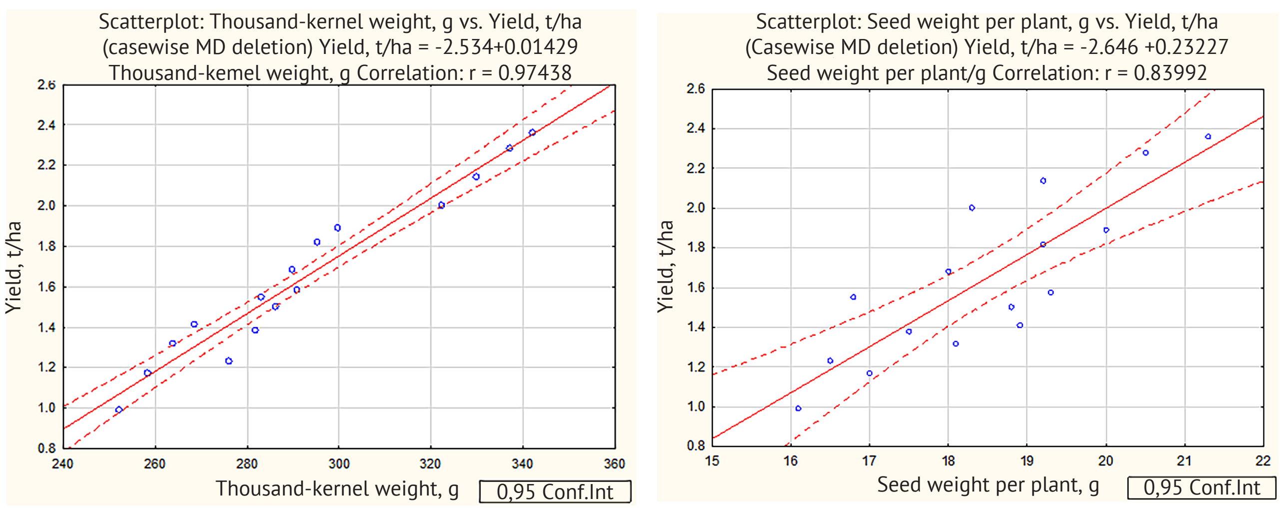
Source: *developed by the authors of this study*

Table 2. *Yield of common chickpea (Cicer arietinum L.)*

Variety (factor A)	Treatment variant (factor B)	Yield, t/ha				
		2021	2022	2023	*mean*	*deviation ±*
Budzhak	control	1.22	1.46	1.01	*1.23*	–
	seed treatment	1.35	1.59	1.19	*1.38*	*+0.15*
	foliar dressing	1.48	1.70	1.32	*1.50*	*+0.27*
	seed treatment + foliar dressing	1.56	1.77	1.41	*1.58*	*+0.35*
Triumf	control	0.98	1.17	0.82	*0.99*	–
	seed treatment	1.15	1.38	0.97	*1.17*	*+0.18*
	foliar dressing	1.29	1.52	1.16	*1.32*	*+0.33*
	seed treatment + foliar dressing	1.37	1.60	1.25	*1.41*	*+0.42*
Pamiat	control	2.03	2.24	1.72	*2.00*	–
	seed treatment	2.18	2.38	1.86	*2.14*	*+0.14*
	foliar dressing	2.35	2.50	2.00	*2.28*	*+0.28*
	seed treatment + foliar dressing	2.43	2.57	2.09	*2.36*	*+0.36*
Odysei	control	1.55	1.80	1.30	*1.55*	–
	seed treatment	1.69	1.93	1.41	*1.68*	*+0.13*
	foliar dressing	1.83	2.08	1.54	*1.82*	*+0.27*
	seed treatment + foliar dressing	1.90	2.15	1.62	*1.89*	*+0.34*
	LSD_{05} (A)	0.36	0.41	0.38		
	LSD_{05} (B)	0.20	0.17	0.20		
	LSD_{05} (AB)	0.39	0.43	0.40		

Source: *developed by the authors of this study*

According to factor A, in 2021-2023, the Pamiat variety substantially outperformed other chickpea varieties in terms of yield. According to factor B, the yield of chickpea after complex treatment with a growth stimulator substantially exceeded this indicator in the control and pre-sowing seed treatment variants. According to the average yield data, the treatment variants exceeded the control by 0.15 t/ha, the foliar dressing option – by 0.29 t/ha, and the seed treatment + foliar dressing variant – by 0.37 t/ha. The average yield of the Pamiat variety was 2.36 t/ha under the complex treatment with the preparation. In addition, according to average data, the greatest impact of complex stimulant treatment was observed in the Triumph variety – 0.42 t/ha. According to the results of correlation analysis, the interrelations of productivity elements with the level of chickpea yield were established. Close correlations were observed between the following parameters: thousand-kernel weight and yield (r = 0.97), and weight of seeds per plant and yield (r = 0.84) (Fig. 3).



a) *b)*

Figure 3*. Correlation of productivity elements with the level of chickpea yield*
Note: *a) relationship between thousand-kernel weight and yield; b) relationship between seeds per plant and yield*
Source: *compiled by the authors of this study*

According to Figure 3, the effect of the growth stimulator on the increase in the yield level of chickpea due to the increase in seed size and plant productivity was noted. Thus, during the cultivation of chickpea, the usual use of complex treatment of seeds and plants with an organic growth stimulator allows increasing the elements of seed productivity and yield level in the conditions of the Central Forest-Steppe of Ukraine.

DISCUSSION

Many studies have been conducted on the effectiveness of growth stimulants in increasing the productivity of pulses. O. Khodanitska *et al*. (2021) found a positive effect of the use of biostimulants during pre-sowing seed treatment and during the growing season, which suggests analogous conclusions to the studies conducted on the subject investigated in the present study. Studies have established the relationship between the resistance of chickpea plants and other indicators. M.I. Kondratenko *et al*. (2020), in their study of chickpea plants resistance to ascochyta leaf blight, highlighted its strong connection with seed size and duration of interphase periods. The researchers found correlations between the average strength of the cold resistance index and plant height and seed size. In the present study, the interrelationships of the elements of chickpea seed productivity with each other and with the yield index were investigated. Establishing the correlations of these parameters with the duration of interphase periods, cold resistance, and resistance to ascochyta leaf blight was not the purpose of this study.

A.V. Bahan *et al*. (2020), based on the findings of studies on the effect of Biomag chickpea preparation on the elements of seed productivity of common chickpea varieties during pre-sowing seed treatment, indicated an increase in the studied indicators compared to the control. The treatment of chickpea seeds with this preparation contributed to an increase in the following indicators: plant height by 8.4%, the number of beans per plant by 14.4%, the number of seeds per plant by 17.5%, the number of seeds per bean by 3.6%, which suggests the effectiveness of using the Biomag chickpea preparation. The present study established the effectiveness of the use of growth regulators not only for pre-sowing treatment of chickpea seeds, but also for the complex application of the preparation (seed treatment + foliar dressing).

O.V. Ovcharuk *et al*. (2019) found a positive effect of growth regulators on increasing yields by 8-17%. In their study, the researchers point out that the effectiveness of these products depends on a series of factors, namely: varietal properties, processing methods, and growing conditions. I.M. Didur and M.O. Mordvaniuk (2018) and I.M. Didur *et al*. (2020) note that the findings of 2016-2017 studies revealed an increase in the yield of common chickpea under pre-sowing seed treatment with the Biomag chickpea inoculant and two-time foliar dressing of plants with the organic microfertiliser Urozhai Bobovi, compared to the control, which was 0.61 t/ha and 1.12 t/ha, respectively. The researchers noted that when growing common chickpea, the most favourable conditions for yield formation were found during seed treatment with an inoculant and two foliar dressings with microfertiliser in the interphase period "intensive growth – budding".

M. Mordvaniuk *et al*. (2019) also found a positive effect of using inoculation of chickpea seeds with Biomag chickpea and two foliar dressings with Urozhai Bobovi microfertiliser on increasing the yield level by 0.62-0.68 t/ha compared to the control. In the current study, a positive effect of the growth stimulator was noted on both the elements of seed productivity and the level of yield when used in combination with seed treatment and foliar dressing. M.I. Kondratenko *et al*. (2020) established medium-strength correlations between the number of beans per plant and the number of seeds per bean with plant productivity ($r = 0.64$ and $r = 0.56$, respectively), between the weight of seeds per plant and the thousand-kernel weight ($r = 0.65$). A.Ye. Titova (2018) notes strong correlations between the traits of number of beans per plant and number of grains per plant ($r = 0.82$), number of beans per plant and plant productivity ($r = 0.81$), as well as medium strength of the relationship between plant height and seed weight per plant ($r = 0.54$), and therefore, she recommends selecting samples according to the selected traits. The findings of these studies showed a correlation between the thousand-kernel weight and plant productivity ($r = 0.77$), as well as a strong correlation between the number of beans per plant and the number of seeds per plant ($r = 0.91$).

Thus, in the context of climate change, it is necessary to pay attention to some elements of chickpea cultivation technology, in particular the use of humic plant growth stimulants depending on the timing and methods of treatment.

CONCLUSIONS

According to the findings of the study, the effectiveness of the combined use of the preparation during pre-sowing seed treatment and fertilisation of chickpea plants during the growing season was established. This treatment variant contributed to an increase in the manifestation of productivity elements of chickpea by more than 10.0% compared to the control (without treatment). The indicator of seed weight per plant in this variant of the experiment increased by 24.0%. Among the varietal composition, the Pamiat chickpea variety can be distinguished by such productivity elements as plant height, seed weight per plant, and thousand-kernel weight. According to the level of manifestation of biometric parameters, the Triumf chickpea variety was distinguished by the number of beans and seeds per plant, the number of seeds per bean. The Pamiat chickpea variety was distinguished by the level of yield under the variant of complex application of the preparation. However, the greatest increase in yield in this variant of the experiment was observed in the Triumf variety (29.8%) compared to the Pamiat variety (15.3%).

Close correlations were established between the weight of seeds per plant and the thousand-kernel weight, as well as beans per plant and seeds per plant. The dependence of chickpea yield on plant productivity and thousand-kernel weight was noted. Thus, the complex use of a growth stimulator contributed to the growth of chickpea yield by increasing plant productivity. The prospect of further research is to investigate the effect of complex application of the growth stimulator Foliar Concentrate on the level of adaptability of chickpea plants.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Вплив гумінових стимуляторів росту на продуктивність сортів нуту звичайного (*Cicer arietinum* L.)

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Анотація. За умов органічного землеробства поширення набуло використання біостимуляторів росту рослин у технологіях вирощування сільськогосподарських культур, зокрема і нуту звичайного. Мета досліджень: вивчення прояву елементів продуктивності та рівня урожайності сортів нуту звичайного залежно від обробки органічним стимулятором росту. Під час досліджень використовували наступні методи: польовий – для визначення рівня урожайності, лабораторний – для вивчення елементів продуктивності нуту звичайного та статистичний – для оцінки достовірності експериментальних досліджень. Було виділено за варіантами обробки комплексне застосування препарату під час передпосівної обробки насіння та позакореневого підживлення рослин у період вегетації. Було відмічено вплив органічного стимулятора росту на збільшення елементів продуктивності нуту звичайного за даним варіантом досліду у середньому на 10,0 %. Було встановлено найбільший вплив препарату за комплексної обробки насіння і рослин нуту звичайного за показником маси насіння з рослини (24,0 %). Було виділено за впливом сортових властивостей на елементи продуктивності нуту звичайного сорти Тріумф і Пам'ять. Було відмічено за показником урожайності нуту звичайного сорт Пам'ять з варіантом обробка насіння + позакореневе підживлення, але найбільший вплив стимулятора росту на приріст урожайності відмічено у сорту Тріумф. Було встановлено тісні взаємозв'язки маси насіння з рослини із масою 1000 насінин, кількості бобів на рослині із кількістю насінин з рослини, а також урожайності із продуктивністю рослини та масою 1000 насінин. Результати дослідження рекомендовано використовувати для корегування елементів технології вирощування нуту звичайного з метою підвищення продуктивності у виробничих умовах

Ключові слова: обробка насіння; позакореневе підживлення; урожайність; елементи продуктивності