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Effect of pre-sowing seed inoculation and foliar dressing on grain productivity and symbiotic activity of chickpea plants

Abstract. The relevance of the study lies in the fact that in the context of the rapid pace of global climate change and war in Ukraine, farmers are interested in finding modern and innovative approaches that would allow obtaining high yields and optimising acreage in the Right-Bank Forest-Steppe zone, considering their reduction in those areas where sustainable chickpea grain cultivation was ensured. The purpose of the study was to substantiate and show the importance and necessity of using trace elements for foliar dressing, both in variations with and without seed inoculation. It was found that pre-sowing inoculation of chickpea seeds and the use of the trace element boron in double foliar top dressing during intensive growth (budding) and in the flowering phase at its initial stage provides a specific effect on the symbiotic activity of bacteria of the genus Rhizobium and grain productivity of chickpea plants. During pre-sowing seed treatment with bioinoculant BTU®-p and carrying out two foliar dressings in two different phases with microfertiliser Help Rost®-Boron, there was a significant increase in the weight and number of nodule bacteria, the weight of 1,000 seeds, germination energy, green mass, and plant height, which ultimately had an excellent effect on the final yield indicators of various variants compared to the control. The maximum weight and number of nodules during the research period was formed in the flowering phase, namely, at the end of this phase. The largest number of nodule bacteria was 38.2 units/plant with a weight of 625.1 mg/plant on roots and root hairs was recorded in the variant with sowing of the Triumph variety, where two foliar dressings with microfertilisers and pre-sowing seed treatment with BTU®-p inoculant were used, which as a result exceeded the control by 11.2 units/plant and 24.9 mg/plant in the same growing season of the plant. It was found that the use of pre-sowing inoculation of chickpea seeds and foliar dressing during two different phases of vegetation allowed increasing the yield to 3.07-3.18 t/ha

Keywords: nitrogen-fixing nodules; pre-sowing seed treatment; trace elements; variety; *Rhizobium* bacteria; growing season phases; drought resistance

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INTRODUCTION

Chickpea *Cicer arietinum* L. is one of the oldest crops known to mankind, it was grown in Mesopotamia, Ancient Egypt, and Greece. Ukraine has all the prerequisites for expanding the acreage of chickpeas, especially in the southern and central regions, where climatic conditions favour its vegetation (Shcatula *et al*., 2024). Chickpea is one of the most promising and valuable among leguminous crops in terms of various taste and nutritional properties. Chickpea seeds, depending on the variety, contain from 20.1 to 32.4% protein, which is easily digested unlike other legumes, and has a high index of essential amino acids (38.51%), methionine (3.11%), lysine (7.65%), isoleucine (6.81%), and tryptophan (1.10%). According to these indicators, chickpeas are superior to peas, beans, lentils by about 3-7%, and second only to soybeans. Chickpeas are a good source of B vitamin complex (B1, B2, B6, PP), micro- and macronutrients, and contain 50-60% easily digestible carbohydrates and up to 7% fat (Kalenska & Okhota, 2018).

The prospect of growing chickpeas is not only to solve and solve food security problems, but also that due to the fact that the root system contains nodule bacteria, this allows fixing nitrogen from the air and enriching the soil with it, and root secretions with high acidity allow quickly dissolving phosphates. Therefore, as noted by Y. Romanko *et al.* (2024), after harvesting, the plant leaves up to 80-120 kg/ha of nitrogen in the soil. This allows increasing the yield of crops that will be in the crop rotation in the future, reduce the application rates of synthetic nitrogen fertilisers, thereby reducing mechanical and chemical loads on the soil, save money, and protect the environment.

In addition to its agronomic advantages, the growing demand for chickpeas on the global market is also important. Interest in it is conditioned only by its high nutritional value, but also to healthy eating trends and the growing popularity of vegetarian and vegan diets. Countries such as India, Turkey, Pakistan, and Egypt remain the largest consumers and importers of chickpeas, which opens up export prospects for Ukrainian producers, according to S. Sots *et al*. (2023). However, despite the significant potential of chickpea cultivation, producers face a number of challenges, including vulnerability to diseases, pests, adverse weather conditions, and restrictions related to the genetic diversity of the crop (Kryvenko *et al*., 2023). That is why it is important to conduct scientific research aimed at investigating the agrobiological features of chickpeas, developing new varieties with improved characteristics, and improving technologies for growing, storing, and processing. One of the key factors for the growth and development of chickpeas is drought resistance, which is higher than that of soybeans and peas. By doing this, the plant has the ability to produce consistently high yields in the face of climate change, and due to the deep-penetrating tap root system, chickpea plants accumulate nutrients better and consume moisture more economically. According to A. Dobrovolsky *et al*. (2020), to increase the competitiveness of chickpeas, it is necessary to improve their cultivation technologies, including adaptation to climate change, selection of disease-resistant varieties, and the introduction of modern agricultural technologies. Investments in the development of the processing industry, in particular, the production of chickpea flour and protein concentrates, can contribute to creating added value and strengthening Ukraine's position in the international leguminous market (Rakhmentov *et al*., 2023).

Thus, chickpeas are a promising crop for the development of the Ukrainian agricultural sector. Its cultivation not only increases soil fertility and reduces fertiliser costs, but also opens up new economic opportunities for farmers and exporters. Given the current trends in agriculture and the food industry, further research and popularisation of chickpeas can contribute to strengthening food security and sustainable development of agricultural production in Ukraine. Therefore, the purpose of this study was to consider relevant scientific approaches to the investigation of chickpeas, its food and agronomic value, the main problems facing the industry, and the prospects for the development of this crop in the context of global challenges related to ensuring food security and sustainable agricultural development.

LITERATURE REVIEW

Researchers from all over the country have devoted years of their research to the issues of global chickpea production, its importance for world food and the role of Ukraine in this. Thus, H. Pantsyreva (2024) revealed the features of the development of yield and quality of chickpea seeds depending on the varietal composition, pre-sowing treatment with a bacterial preparation, and the use of different concentrations of retardant. Based on the results of the study, it was determined that the best results were observed when treating seeds with Rizohumin-Plus and twice spraying crops with chlormequat-chloride retardant: the first time – in the phase of the third tripinnately compound leaf, the second – in the budding phase. The highest content of crude protein and fat in chickpea seeds was recorded in the Pegas variety (30.42% and 4.84%) and the Skarb variety (27.66% and 3.61%). Such indicators were obtained during pre-sowing treatment of seeds with the bacterial preparation Rizohumin-Plus and double spraying of plants with a 0.75% retardant solution during the growing season. It was proved that the use of chlormequat chloride (0.75%) in the phases of the third tripinnately compound leaf and budding creates optimal conditions for the growth and development of high yield of chickpeas of the Skarb and Pegas varieties, which is 2.53-3.02 t/ha.

The study by I. Didur & M. Temchenko (2017) explained the importance of regulating chickpea crop density for optimal plant development and yield. Since the density of sowing is an important factor, it affects the rate of plant development, morphological features, generative organs, and flowering time. Density control can regulate development: depending on the characteristics of the crop, increasing or decreasing density can accelerate or slow growth. Negative effects of excessive thickening: because chickpeas are prone to branching, in dense crops, plants compete for light, moisture, and nutrients, which reduces the productivity of each individual plant. According to the study, the highest chickpea plants in terms of the main phases of growth and development during seed inoculation and double fertilisation with microfertilisers were in the Pegas variety – branching – 33.7 cm, budding – 48.7 cm, flowering – 61.5 cm, physiological ripeness – 60.1 cm. The highest density of plant standing was observed during pretreatment of seeds with Biomag Nut inoculant and double fertilisation with microfertilisers during the period of physiological ripeness – 529 thousand units/ha, survival rate – 88%. Therefore, density should be considered as one of the important factors that, in combination with others, can positively affect the yield. By changing the sowing density, it is possible to influence the pace of plant development, morphology, the time of laying generative organs and flowering, and thus, depending on the biological characteristics of the plants, accelerate or slow down their development.

The purpose of the study by V. Mazur *et al.* (2021) was to investigate the impact of aspects of chickpea cultivation technology, considering the economic efficiency of these methods. In the study, the highest rates of net profit and profitability were obtained by pre-treating seeds with Rizolin + Rizosave bioinoculant and two foliar fertilisations with Urozhai Bobovi microfertiliser and amounted to 17,815 UAH/ha and 155% in Pegas variety, which is 68% more than in the control, and 15,793 UAH/ha and 139% in Triumph variety, respectively, which is 62% more than in the control. The analysis of economic indicators in this paper showed that in the conditions of the Right-Bank Forest-Steppe on grey forest soils, the intensification of chickpea cultivation under the condition of seed treatment before sowing and double foliar dressing is a cost-effective method. From an economic standpoint of view, the most effective way is to grow chickpeas of the Pegas variety using bacterial preparations Rizoline + Rizosave during pre-sowing seed treatment and two foliar dressings with microfertiliser Urozhai Bobovi. Each of the researchers contributed to the solution of tasks of different types and nature and proved that these studies can be used to improve the technology of growing chickpeas.

With the growing popularity of healthy eating, Ukrainians are increasingly paying attention to the beneficial properties of chickpeas, a legume that is still a relatively new crop for Ukraine. Moreover, this plant ranks third in the world in terms of crop area, second only to soybeans and beans. Chickpeas are in high demand on the global market, especially in Central Asia, East Africa, Europe, and the Mediterranean region (Koloianidi, 2021). Chickpea cultivation is economically profitable for farmers due to stable demand, high profitability, and the ability to export products to international markets. Its grains are widely used for making soups, side dishes, pastries, national dishes, and as a component of animal feed. Global chickpea crops cover up to 13 million hectares. The leader in cultivation is India, which provides up to 70% of the world's land area, followed by Australia with 5-10%, Pakistan – up to 5%, and Turkey – about 4% (Honchar, 2023). Ukrainian farmers are also increasingly choosing chickpeas for cultivation. Thus, according to the State Statistics Service of Ukraine (n.d.), in 2018, about 36 thousand hectares were sown, and in 2019 the area increased to 46.9 thousand hectares, with a yield of 1.0 to 4.0 t/ha. The main growing regions are Odesa, Zaporizhzhia, Mykolaiv, Chernivtsi, and Vinnytsia oblasts. For example, farms in the Odesa Oblast noted a significant increase in yield due to the introduction of modern agrotechnical technologies, which indicates the successful experience of growing this crop in Ukraine.

In addition, chickpeas, like other legumes, play an important role in animal husbandry, as they help to solve the problem of providing feed protein. It is used for the production of mixed feeds, in particular, as a source of protein for cattle, pigs, and poultry. The high protein content of chickpea seeds improves the growth and development of animals, increases their productivity and overall health. This crop also helps to improve soil fertility, reducing the environmental burden on the agrobiocenosis. Under favourable conditions such as moderate temperature, sufficient rainfall or efficient irrigation, providing fertile soil with a neutral pH level and balanced fertilisation, and proper care, including timely weed removal and pest protection, chickpea yields can exceed 3.0-3.5 t/ha (Kolesnikov & Kadyrov, 2022).

Chickpeas are also an effective precursor for cereals, as they help to increase their yield, often exceeding the indicators after black fallow. According to Y. Rakova (2021), chickpeas are unpretentious to the type of soil, but grow best on light chernozems, dark chestnut soils, because such soils provide optimal aeration of the root system, retain sufficient moisture, and have a high content of nutrients, which contributes to healthy plant growth and the development of high yields, with a neutral or slightly alkaline reaction (pH 6.5-8.5). Heavy, acidic, or waterlogged soils negatively affect plant growth, increasing the risk of root rot. Chickpeas respond positively to a balanced diet and make good use of the remnants of organic and mineral fertilisers applied under the previous crop. The consumption of macro- and microelements depends on the planned yield and the results of agrochemical soil analysis. For example, for a yield of 2.0 t/ha, it is necessary to provide 106 kg of nitrogen, 36 kg of phosphorus, 150 kg of potassium, and 23 kg of magnesium.

The issues of stress tolerance were considered in the paper by A. Bahan (2023), considering weather conditions, varietal characteristics, seeding rates, and sowing methods. It was found that with the conventional row method, the optimal seeding rate is 1.0 million seeds/ha, while with a row spacing of 45 cm – 0.8 million/ha using $N_{30}P_{60}K_{60}$. The yield increases by 0.12 t/ha. According to V. Pushchak (2018), Privo 1 and Krasnokutskyi 36 varieties are recommended to be sown at a rate of 1.0 million/ha, and the Zolotyi Yuvilei variety – 0.7 million/ha. With a wide-row seeding method, the optimal rate is 0.8 million/ha. According to N. Koloianidi (2019), the yield of the Pamyat variety without fertilisation was 2.42 t/ha, and with the addition of phosphorus and potassium it increased to 2.60 t/ha. A further increase in fertiliser doses contributed to an increase in yield to 2.74-2.82 t/ha, which is 13.2-16.5% more. Additional nitrogen application further improved the results.

When laying a grain crop, the quality and quantity of products directly depend on climatic conditions. Favourable weather conditions such as optimal temperatures, precipitation levels, and other factors can significantly increase yields, while adverse conditions such as droughts or excessive rains can significantly reduce this rate (Mazur & Pinchuk, 2022). In this regard, to ensure stable chickpea production in regions with unstable environmental conditions, it is important to use varieties that can adapt to variable factors and demonstrate the highest efficiency in such conditions. According to O. Tryhuba *et al.* (2024), the choice of such varieties can reduce risks and ensure a high yield even in adverse weather conditions. Despite the presence of a large number of studies, every year there is a need to review and introduce new results and proposals, considering new global and national interests and trends.

MATERIALS AND METHODS

Field research to investigate and obtain the results of the impact of seed treatment with BTU®-p inoculant before sowing and two-time foliar application of Help Rost®-Boron (B) microfertiliser on the quantitative and qualitative indicators of chickpea yield and symbiotic productivity was conducted at the Agronomichne research site of Vinnytsia National University, located in the village of Agronomichne, Vinnytsia district (Ukraine) during 2023-2024. The soil cover consisted of grey forest soils, which are typical of temperate climates with moderate humidity. The depth of the humus-eluvial horizon reached 30 cm, its colour – grey, which indicates an average level of fertility. According to the results of the soil survey, the soils of the experimental site are characterised by a low humus content of up to 2%. This indicates the need to take additional measures to improve soil fertility. The content of alkaline hydrolysed nitrogen (Kornfield method) was 70 mg/kg of soil, which indicates the average level of soil nitrogen supply. Mobile phosphorus (Chirikov method) was contained in the amount of 145 mg/kg of soil, and exchange potassium (Chirikov method) – 95 mg/kg of soil, which also meets the standards for agricultural land in this category. The content of absorbed bases was 1.30 mg-Eq. per 100 g of soil, which indicates a certain level of alkaline environment in the soil (Nastiuk, 2023). The hydrolytic acidity is 3.5 mg-Eq./100 g of soil, which indicates moderate acidity. The reaction of the soil solution varied from 5 to 5.5 pH, which means a slightly acidic reaction that is optimal for many crops. The main amount of water and the process of moistening the soil occurs due to precipitation, since the ground water level is at a depth of up to 15 m, which makes the soil more stable in conditions of variable humidity and the absence of precipitation for a long time. However, depending on weather conditions, the moisture content in the soil may vary. The agrochemical characteristics of grey forest soils are shown in Table 1, which allows assessing the condition of the soils and developing appropriate recommendations for their improvement for agricultural needs.

Table 1. Agrochemical indicators of soils of the research site Agronomichne (based on the materials of the soil survey 2020)

Soil profile depth, cm	Humus, %	pH	Hydrolytic acidity, mg/100 g of soil	Absorbed bases, mg/100 g of soil	Degree of saturation with the bases, %
0-20	2	5.5	3.65	14.8	85
30-40	1.58	5.3	3.6	14	96
65-75	0.84	5	3.47	13.8	83
95-105	Not defined	4.9	3.35	13.6	84
125-135	Not defined	4.7	3.1	13.3	88

Source: compiled by the author based on the research by A. Nastiuk (2023)

After analysing climate data for the period 2023-2024, it was found that hydrothermal conditions in this region are very favourable for chickpea cultivation (Table 2).

Table 2. Precipitation and temperature (per first ten days of month) during the growing season of agricultural crops in the period 2023-2024

Month	Ten days	Temperature, °C			Amount of precipitation, mm		
		Average for the growing season	2023	2024	Average for the growing season	2023	2024
April	1	13.1	12.1	14.1	24.5	49	0
	2	11.1	10.9	11.4	39	25	53
	3	12.5	12.3	12.7	28	9	47
	per month	12.2	11.7	12.7	91.5	83	100

Table 2, Continued

Month	Ten days	Temperature, °C			Amount of precipitation, mm		
		Average for the growing season	2023	2024	Average for the growing season	2023	2024
May	1	15.4	15.1	15.7	3	1	5
	2	14.8	15.3	14.3	0	0	0
	3	18.5	16.4	20.6	21.5	1	42
	per month	16.2	15.6	16.8	24.5	2	47
June	1	20.95	21.3	20.6	51.5	23	80
	2	19.35	20.4	18.3	46.5	46	47
	3	22.5	22.6	22.4	10	14	6
	per month	20.9	21.4	20.4	108	83	133
July	1	26.2	25.6	26.9	22.5	27	18
	2	28.2	27.3	29.2	3.5	4	3
	3	26.1	28.1	24.2	43.5	23	64
	per month	26.8	27	26.7	69.5	54	85
August	1	22.6	23.1	22.1	16.5	19	24
	2	23.8	23.4	24.3	0	0	0
	3	25.2	24.8	25.6	6.5	13	0
	per month	23.8	23.8	24	28	32	24
April-August		19.9	19.9	20.1	64.3	254	389

Source: created by the author based on Meteoblue data (n.d.)

The study examined the influence and interaction of three factors, namely:

Research factors:

1. Plant varieties (A):

A. Triumph;

B. Pamyat.

2. Methods of pre-sowing seed treatment (B):

A. Without seed treatment before sowing;

B. Bioinoculant BTU®-p (3 l/t).

3. Foliar dressing (C):

A. Without dressing (control option);

B. One fertilisation with Help Rost®-Boron microfertiliser (3 l/ha) during intensive growth (budding phase);

C. One fertilisation with Help Rost®-Boron microfertiliser (3 l/ha) in the initial flowering phase.

The study met the requirements of Convention on Biological Diversity (1992) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

In the course of the study, it was found that there is a dependence on pre-sowing treatment for chickpea seeds with BTU®-p inoculant (3 l/t); and the use of Help Rost®-Boron microfertiliser (3 l/ha) for two foliar dressings. The legume harvest showed a positive trend in the growth of certain quantitative and qualitative indicators of the chickpea harvest, and especially an increase in the symbiotic activity of *Rhizobium* bacteria, in particular, their number and weight, as shown in Table 3.

Table 3. Dependence of the weight and number of nodule bacteria on seed inoculation and foliar dressing (2023-2024)

Variety	Inoculation	Fertilisation	Budding		Beginning of flowering		End of flowering		Full seed filling	
			Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant
Triumph	BTU®-p (3l/t)	Help Rost®-Boron 3 l/ha (2 dressings)	13.1	73.5	33.4	260.5	38.2	625.1	30.6	170.6
Triumph	BTU®-p (3l/t)	Help Rost®-Boron 3 l/ha (1 dressing)	12.5	72.1	31.5	256.4	36.7	621.3	28.7	162.9

Table 3, Continued

Variety	Inoculation	Fertilisation	Budding		Beginning of flowering		End of flowering		Full seed filling	
			Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant	Number of nodules, units/plant	Nodule weight, mg/plant
Triumph	BTU®-p (3l/t)	–	11.9	68.3	30.7	245.6	35.5	609.6	27.5	158.4
Triumph	–	Help Rost®-Boron 3 l/ha (2 dressings)	10.3	66.2	28.2	242.3	32.3	608.1	24.2	150.1
Triumph	–	Help Rost®-Boron 3 l/ha (1 dressing)	10.2	64.4	27.2	238.4	31	606.4	23.1	148.9
Triumph	Control	Control	9.3	61.1	24.1	221.5	27	600.2	21.4	135.8
Pamyat	BTU®-p (3l/t)	Help Rost®-Boron 3 l/ha (2 dressings)	12.5	71.4	31.2	252.3	36.4	614.8	28.9	163.4
Pamyat	BTU®-p (3l/t)	Help Rost®-Boron 3 l/ha (1 dressing)	12.1	70.2	30.4	251.4	35.2	610.8	27.6	162.1
Pamyat	BTU®-p (3l/t)	–	11.7	65.4	29.5	248.6	33.1	605.4	26.4	158.6
Pamyat	–	Help Rost®-Boron 3 l/ha (2 dressings)	10.9	66.9	26.1	250.1	31.4	607.8	24.2	160.4
Pamyat	–	Help Rost®-Boron 3 l/ha (1 dressing)	10.8	66.1	25.9	249.4	31.1	606.1	23.5	158.7
Pamyat	Control	Control	9.1	60.4	23.8	216.5	26.1	601.4	21.3	132.7

Source: developed by the author

The first indicator of the amount and their weight on the roots of chickpea plants was carried out in the budding phase, where the best indicator was in the Triumph variety, where an inoculant and two dressings were used. The number of bacteria was 13.1 units/plant, and their weight was 73.5 mg/plant. The worst result was recorded in the control where the number of nodules numbered 9.3 units/plant and had a weight of 61.1 mg/plant. The indicators of the Pamyat variety had a slightly worse situation, but it was similar to the Triumph variety. The best results among the 6 variants were observed where pre-sowing treatment of seeds with inoculant and two dressings were applied. The number of bacteria was 12.5 units/plant, and their weight was 71.4 mg/plant. The worst result was the control, where the weight of nodules was 9.1 mg/plant, and their number was 60.4 units/plant.

The next accounting of the weight and number of nodules on the roots of plants was carried out at the stage of completion of flowering. In the control variant for the Triumph variety, 27 nodules were recorded per plant with a weight of 600.2 mg. The highest indicator of the number and weight of nodules was observed when using pre-sowing seed treatment and double dressing with microfertilisers. In this case, 38.2 nodules per plant weighing 625.1 mg were found on chickpea roots. This result was confirmed by observations during excavation and root washing, when a significant number of red nodules were visible, indicating active symbiosis and nitrogen accumulation.

Compared to the control, the increase was 11.2 nodules per plant and 24.9 mg of weight in the same growing season. The average growth of nodules compared to the control was from 3.8 to 9.2 nodules per plant. The analysis of variance showed that all increments are reliable, since they exceed the least significant difference (LSD). As a result of the study, it was found that the most effective method for increasing the number and weight of nodules is pre-sowing seed treatment with BTU®-p inoculant (3 l/t) and double foliar dressing with Help Rost®-Boron microfertiliser (3 l/ha). This ensured the development of the maximum indicator of nodules at all stages of plant growth. An important indicator in the study was the yield. Its development largely depended on the annual growing conditions, but the factors tested also had a significant impact on the crop growth trend, as shown in Table 4.

Table 4. Dependence of chickpea yield on inoculation and dressing t/ha (2023-2024)

Variety	Inoculation	Dressing	Yield, t/ha		Average yield, t/ha	increase in control, t/ha		increase in control, %	
			2023	2024		2023	2024	2023	2024
Triumph	BTU®-p	Help Rost®-Boron 3 l/ha (2 dressings)	3.16	3.20	3.18	0.76	0.90	31.67	39.13
Triumph	BTU®-p	Help Rost®-Boron 3 l/ha (1 dressing)	2.84	2.96	2.90	0.44	0.66	18.33	28.70
Triumph	BTU®-p	–	2.6	2.65	2.63	0.20	0.35	8.33	15.22
Triumph	–	Help Rost®-Boron 3 l/ha (2 dressings)	2.76	2.80	2.78	0.36	0.50	15.00	21.74
Triumph	–	Help Rost®-Boron 3 l/ha (1 dressing)	2.70	2.75	2.73	0.30	0.45	12.50	19.57
Triumph	Control	Control	2.4	2.3	2.35	–	–	–	–
Pamyat	BTU®-p	Help Rost®-Boron 3 l/ha (2 dressings)	3.03	3.11	3.07	0.68	0.86	28.94	38.22
Pamyat	BTU®-p	Help Rost®-Boron 3 l/ha (1 dressing)	2.8	2.91	2.86	0.45	0.66	19.15	29.33
Pamyat	BTU®-p	–	2.5	2.53	2.52	0.15	0.28	6.38	12.44
Pamyat	–	Help Rost®-Boron 3 l/ha (2 dressings)	2.54	2.62	2.58	0.19	0.37	8.09	16.44
Pamyat	–	Help Rost®-Boron 3 l/ha (1 dressing)	2.48	2.56	2.52	0.13	0.31	5.53	13.78
Pamyat	Control	Control	2.35	2.25	2.30	–	–	–	–

Source: developed by the author

When analysing the studied factors affecting the yield of chickpeas, a noticeable increase in yield was revealed in comparison with the results obtained at the control. Table 4 showed that the lowest yield was recorded in the control, where dressing and seed inoculation were not carried out and amounted to 2.35 t/ha for the Triumph variety and 2.3 t/ha for the Pamyat variety. In the variant where two dressings was carried out, the yield increased by 0.43 t/ha to 2.78 t/ha for the Triumph variety, and by 0.22 t/ha to 2.52 t/ha for the Pamyat variety. The best yield was demonstrated in the variant where pre-sowing seed inoculation and two foliar treatments were used. The yield of the Triumph variety increased by 0.83 t/ha to 3.18 t/ha, and by 0.77 t/ha to 3.07 t/ha for the Pamyat variety. Therefore, these results indicate that when growing chickpeas, the best conditions for the growth and development, namely, the crop, were formed when using pre-sowing seed treatment with inoculant and two dressings was carried out in the budding phase and the beginning of flowering.

The study by M. Mordvaniuk (2019) found that the best results in the number and weight of nodule bacteria at the end of flowering and yield of chickpeas were observed with double foliar treatment with microfertiliser (Urozhai Bobovi) and pre-sowing seed inoculation (Biomag Nut) where the amount is 39.2 units/plant, weight – 611.4 mg, with an average yield of 2.92 t/ha for 3 years of research. L. Poberezhna (2023) substantiated the importance of foliar top dressing with trace elements (boron) and (molybdenum). It was found that the best results were demonstrated at the site where the Pamyat variety was grown with pre-sowing application of mineral fertilisers at the rate $N_{30}P_{20}K_{20}$ and foliar top dressing with boron and molybdenum. The yield at this experimental site was 2.54 t/ha. The results of this study correspond to the findings of other researchers. Moreover, the results obtained are slightly better compared to M. Mordvaniuk (2019), and compared to L. Poberezhna (2023), the results of the current study are much better. Thus, the results of the study confirmed the effectiveness of using pre-sowing seed inoculation and foliar top dressing to increase the yield of chickpeas, which is consistent with the data of other researchers, demonstrating the potential for optimising agrotechnical techniques to increase the productivity of this crop.

CONCLUSIONS

In the course of the study, the significance and importance of pre-sowing seed treatment with BTU®-p inoculant and the use of two dressings with Help Rost®-Boron microfertiliser (3 l/ha) on chickpea yield and the activity of symbiotic bacteria of the genus *Rhizobium* were investigated and analysed. The results showed that the combination of these agrotechnical measures is most effective for ensuring high yield indicators, improving biological nitrogen fixation and increasing plant resistance to adverse conditions. The best indicators of average yield for two years of research were achieved on variants using an inoculant and two dressings: 3.18 t/ha for the Triumph variety and 3.07 t/ha for the Pamyat variety. This indicates the high efficiency of the technology. Control variants, without the use of inoculant and fertilisation, showed the lowest yield: 2.35 t/ha for the Triumph variety and 2.30 t/ha for the Pamyat variety. The average yield increase in the treated variants ranged from 0.77 to 0.83 t/ha, which is a significant increase relative to the control.

Regarding the symbiotic activity of the *Rhizobium* bacteria, the highest number and weight of nodule bacteria was observed in the Triumph variety on variants with two dressings and inoculation: 38.2 nodules/plant with a weight of 625.1 mg. In the Pamyat variety, the highest indicators were also recorded on similar variants: 36.4 nodules/plant with a weight of 614.8 mg. Control variants showed the lowest rates: an average of 21.4 nodules/plant and a weight of 135.8 mg. This indicates the importance of inoculation and feeding to increase symbiotic activity, which is the basis of biological nitrogen nutrition in plants. Therefore, this study confirmed the high efficiency of agrotechnological measures that were implemented. The use of seed inoculation and microfertilisers significantly increased not only yield, but also symbiotic productivity. That is why it is planned to conduct a study of the third year in order to obtain the best results and confirm the feasibility of implementing these measures in chickpea cultivation to increase productivity, economic profitability, and environmental sustainability of agricultural production of this crop in Ukraine.

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CONFLICT OF INTEREST

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Вплив передпосівної інокуляції насіння і позакореневих підживлень на зернову продуктивність та симбіотичну діяльність рослин нуту

Анотація. Актуальність дослідження полягає у тому, що в умовах швидкого темпу глобальної зміни клімату та війни в Україні аграрії зацікавлені у пошуку сучасних та інноваційних підходів, що даватимуть змогу отримати високі врожаї та оптимізувати посівні площі у зоні Лісостепу Правобережного з огляду на їх скорочення в тих зонах, де забезпечувалося стале вирощування зерна нуту. Метою статті було обґрунтувати та показати важливість та необхідність застосування мікроелементів для позакореневих підживлень як у варіації з інокуляцією насіння, так і без неї. Досліджено, що передпосівна інокуляція насіння нуту та застосування мікроелементу бор у дворазовому позакореневому підживленні під час інтенсивного росту (бутонізація) та у фазі цвітіння на її початковій стадії завбачає питомий вплив на симбіотичну діяльність бактерій роду Rhizobium та зернову продуктивність рослин нуту. Під час передпосівної обробки насіння біоінокулянтом БТУ®-р та проведення двох позакореневих підживлень у двох різних фазах мікродобривом «Help Rost® – Бор» спостерігалося значне збільшення маси та кількості бульбочкових бактерій, маси 1000 насінин, енергії проростання, зеленої маси та висоти рослин, що у підсумку відмінно позначилося на кінцевих показниках врожайності різних варіантів у порівнянні з контролем. Досліджено, що максимальна маса та кількість бульбочок за період проведення досліджень була сформована у фазі цвітіння, а саме в кінці цієї фази. Найбільша кількість бульбочкових бактерій – 38,2 шт./рослину з масою 625,1 мг/рослину на коренях та кореневих волосках була зафіксована у варіанті з посівом сорту Тріумф, де застосовувалися два позакореневі підживлення мікродобривом та передпосівна обробка насіння інокулянтом БТУ®-р, що в результаті перевищило контроль на 11,2 шт./рослину і 24,9 мг/рослину в один і той самий період вегетації рослини. Встановлено, що використання передпосівної інокуляції насіння нуту та проведення позакореневих підживлень під час двох різних фаз вегетації дало змогу підвищити врожайність до 3,07-3,18 т/га

Ключові слова: азотфіксуючі бульбочки; передпосівна обробка насіння; мікроелементи; сорт; бактерії *Rhizobium*; фази вегетації; посухостійкість