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ORIGINAL ARTICLE

Effect of pre-sowing seed treatment and foliar nutrition on productivity and yield of chickpea grain in the eastern forest-steppe of Ukraine

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The results of three-year studies on the influence of elements of cultivation technology on the productivity and grain yield of the chickpea of Rozanna variety are presented. We carried research out based on KhNAU's ESPC's 'Experimental Field' during 2018-2020. The variants of the two-factor experiment were randomly placed using the method of organized repetitions. The sown area is 15 m^2, and the accounting area is 10 m^2. Repetition is repeated four times. Four variants of seed presowing treatment (factor A) were compared in the experiment: 1-control (water moisturizing); 2-seed treatment with an aqueous solution of the preparation Novofert; 3-seed treatment with an aqueous suspension of the preparation *Rhizohumin*; 4-seed treatment with a mixture of Novofert and *Rhizohumin* preparations, as well as two variants of foliar nutrition (factor B): 1-spraying with water; 2-spraying with an aqueous solution of the Novofert preparation. Studies have shown the high efficiency of applying the mixture of inoculant *Rhizohumin* and complex fertilizer Novofert for presowing treatment of chickpea seeds. The significant increase in chickpea plant survival indices has been determined in this variant. The elements of the crop structure that determine the level of crop yield, the number of beans, grains, and grain weight per one plant, have also increased significantly. In particular, the number and weight of grains in the variant of pre-sowing treatment of seeds with a mixture of these preparations, on average during three years, compared to the control were 4.1 and 5.7%, larger accordingly. On the whole, it should be noted that the optimization of chickpea cultivation technology due to presown seed treatment with a mixture of *Rhizohumin* and Novofert complex fertilizer inoculant, followed by foliar nutrition with this fertilizer during the flowering phase, provides a significant increase in grain yield. During the years with different vegetation weather, the grain yield of this variant was 0.37-0.96 t/ha higher than in the control. Providing improved plant growth and development of plants and a significant increase in grain yield, the application of these preparations is ecologically safe and economically profitable, as it does not require significant costs. Complex presowing treatment of chickpea seeds with *Rhizohumin* inoculant with Novofert fertilizer and foliar nutrition of plants in the branching phase, during three years on average provided a grain yield of 4.31 t/ha, which is by 0.58 t/ha higher than in the control.

Keywords: Chickpea, Cultivation technology, Presowing seed treatment, Foliar nutrition, Inoculant, Productivity, Yield.

Introduction

Chickpea is a field crop that can provide sustainable grain yields with a high content of protein in food under the conditions of global climate change (Altaf and Ahmad, 1990; Frias et al., 2000; Bushulyan, 2009; Bushulyan and Sichkar, 2009; Ahmad et al., 2012; Kvitko, Mikhalchuk and Karasevich, 2013; Cobos et al., 2016; Pasichnyk, 2018). In eastern Ukraine, chickpea is not widely spread and not adequately studied, and most recommended technologies for its cultivation are based on general approaches to tillage and crop care (Nepran, Nikolaenko and Stets, 2012; Len, Olepir, and Yeremko, 2016; Rozhkov and Voropay, 2017; Gutyansky et al., 2018; Rozhkov and Voropay, 2019).

In the domestic market, the demand for chickpeas is insignificant, but the export potential of this crop is great. Ignorance of producers about the peculiarities of chickpea cultivation leads to low yields and low grain quality and, as a consequence, makes it impossible to form sales trades shipments (Lebedinskaya, 2017). These problems are the reasons for the decline in economic efficiency of chickpea production (Kalenskaya, Novitskaya and Barzo, 2014; Kovalenko, Korkhova and Tantsyura, 2017; Smikh, 2018; Logosha, Halep and Vorobey, 2020).

Chickpea is a valuable crop in the agrotechnical sense, as it is one of the best predecessors. After harvesting with post-harvest residues there are as many nutrients as in 15-20 tons of manure. Among leguminous plants, chickpea is the most drought-resistant crop. This biological peculiarity of chickpea is explained by a higher content of bound water, due to the fact that transpiration in chickpea crops is lower than in other legumes. During the drought period, chickpea ceases its growth and development, and under favourable conditions it renews them (Patel et al., 2006; Elias and Herridge, 2014; Olika, Abera and Fikre, 2019).

The important role in increasing the yield and improving the grain quality of legumes, especially chickpea, is played by technological aspects of cultivation, but they rarely consider the dependence of biological peculiarities of plant development on external factors and therefore cannot fully reveal the genetic potential of modern varieties (Skitsky and Gerasimova, 2010; Kalenskaya, 2012; Girka et al., 2013; Likhochvor and Pushchak, 2018; Mordvanyuk, 2020).

The intensity of the initial stages of growth is extremely important for the formation of high productivity chickpeas. Therefore, great attention should be paid to preparing the seeds before seed to obtain healthy and friendly seedlings. The quantity and quality of chickpea harvest highly depend on the effective work of the symbionts. At the initial stages of development, phosphorus plays an important role in the formation of nodules, so crops better absorb nitrogen. It also stimulates the development of the root system and activates the laying of generative organs. Boron is important because it enhances the formation of nodules on roots, prevents abortion of flowers, and promotes earlier flowering of plants. For presowing seed treatment, along with bacterization, it is necessary to use a balanced complex of macro, mezo and microelements, since nodule bacteria receive mineral nutrients and carbohydrates from the host plant (Didovich, 2005; Didovich et al., 2005; Kalenskaya, Netupskaya and Novitskaya, 2012; Gospodarenko and Prokopchuk, 2014; Gonchar and Shcherbakova, 2016; Didur and Temchenko, 2017; Potashova and Potashov, 2018; Logosha, Vorobey and Usmanova, 2019; Bagan, Shakali and Barat, 2020).

It is also important to include in the cultivation technology plan the foliar nutrition with modern polymeric fertilizers containing a balanced set of mezo-and microelements, growth activators, antistress elements, etc., to correct mineral nutrition, relieve various stresses and keep plants healthy, due to what plants will realize their genetic potential more fully (Didur and Mordvanyuk, 2019).

Foliar nutrition is one of the effective and ecologically safe measures aimed at meeting the needs of plants in macro and microelements. They make it possible to eliminate timely nutrient deficiencies, prepare plants for stressful conditions caused by unfavourable weather (drought, sudden changes in air temperature), fungal, bacterial, viral diseases, etc. (Yeremko, 2016).

The peculiarities of chickpea grain productivity formation in the conditions of the eastern forest-Steppe of Ukraine are still not adequately studied. Therefore, the clarification of these questions is urgent, it requires scientific substantiation and elaboration of new technological methods of chickpea cultivation, aimed at increasing the activity of biological nitrogen fixation under the conditions of unstable moisture supply and high temperature regime of the Eastern Forest-Steppe of Ukraine.

The purpose of the study was to determine the effect of presowing treatment of seeds and foliar nutrition with multicomponent chelate microfertilizer "Novofert Universal" on the survival of chickpea plants, the formation of its main elements of productivity and grain yield in the conditions of the Eastern Forest-Steppe of Ukraine.

Materials and Methods

We conducted the research based on ESPC "Experimental Field" of KhNAU named after V.V. Dokuchaiev during 2018-2020. The laying of the experiments, observations, accounting, and sampling of plants were carried out according to accepted methods (Rozhkov, Puzik, and Kalenska, 2016). Culture practices of cultivation, except for the elements studied, were accepted for the cultivation area. We carried sowing out with a SSFK-7 selection seeder in a row to a depth of 5 cm in the third decade of April. The sowing rate was 0.85 million pieces/ha. The variants of the two-factor experiment were randomly placed using the method of organized repetitions. The area of the seed plot was 15 m^2, the accounting area was 10 m^2. The repetition was repeated four times.

The experiment contained four options for the pre-sowing seed treatment (factor A): 1-with the water (control); 2-with aqueous solution of the preparation Novofert; 3-with the aqueous suspension of the preparation *Rhizohumin*; 4-with the aqueous mixture of the Novofert and *Rhizohumin* preparations. The experiment also comprised two variants of foliar nutrition (factor B) in the branching phase: 1-with the water; 2-with aqueous solution of the preparation Novofert.

The Rozanna chickpea variety, bred at the Breeding and Genetic Institute and included in the State Register of Plant Varieties Permitted to Grow in Forest-Steppe and Steppe Zones of Ukraine since 2000, was chosen for research. According to the length of the vegetation season, the variety belongs to the group of medium-maturing varieties (95-100 days).

The inoculant Rhizohumin is a preparation of a complex action based on strains of nodule bacteria and physiologically active substances of biological origin. The preparation includes specially prepared peat with Mesorhizobium ciceri cells propagated in it, physiologically active substances of biological origin (auxins, cytokinins, amino acids, humic and fulvic acids), microelements in chelate form, and compounds of macroelements in initial concentrations.

Novofert is a complex, water-soluble fertilizer that contains mezo-(magnesium, calcium, sulfur) and micro-elements (copper, iron, zinc, manganese) in chelate form. Boron and molybdenum are presented in mineral form.

Ecologically safe Novofert preparation is an inductor of plant immunity, it has adaptogenic properties, promotes anti-stress resistance of plants to unfavourable environmental conditions (drought, frost, etc.), has high solubility, increases yields and production quality, and improves the state of plants stimulating better consumption of nutrients from the soil. The preparation is intended for seed treatment and foliar nutrition of plants. The preparation contains, in%: NH_2-20; P_2O_5-20; K_2O-20; B-0.03; Mg-1; S-1.0; Mo-0.003; Mn-0.03; Fe-0.07; Cu-0.05; Zn-0.02 (http://www.novofert.com/ru/razd/item/4-product-uni).

A deficiency of precipitation characterizes the study area. In different years, the amount of precipitation during the vegetation period of crops deviated significantly from the climatic norm index. There were more favorable weather for the vegetation of chickpea plants in 2019 and 2020.

The amount of precipitation in April and May 2018 was three times less than the climatic norm-27 and 77 mm, respectively. Dry weather was accompanied by high temperatures. During some days of the first and third decades of May, it rose above 31.0°C, and moisture deficiency complicated the course of chickpea crop growth processes.

In 2019, from April until July (three months) the precipitation was 250 mm, which is twice the climatic norm. It is also important to note the relatively uniform distribution of precipitation during the growing season of chickpea plants. The temperature regime during the vegetation period, especially at the initial stages, somewhat complicated the course of growth processes of chickpea plants (low temperatures); at the same time, it did not go beyond their biological norm.

The amount of precipitation during the chickpea growing season in 2020 was the lowest, about 60.0 mm, but its distribution was much more uniform than in 2018. The temperature was more favorable for chickpea plants in 2020 than in previous years.

Temperature fluctuations and a significant difference in the amount of precipitation and their distribution during the spring-summer chickpea growing season during the years of research made some adjustments in the growth processes of plants, significantly affecting their yields. At the same time, the differences observed allowed us to analyze more fully the impact of the studied variants of the presowning treatment of seeds and foliar nutrients on the formation of elements of productivity and yield of chickpea grain.

Results and Discussion

One indicator by which you can assess the effectiveness of different variants of cultivation technology or its specific components is the density of plants before harvesting, which, on the one hand, is determined by the seeding rate and, on the other-by plant survival. Under the optimization of the constituent elements of cultivation technology, the survival of plants will be greater. In addition, often in variants with higher plant survival, at the same rate of seed sowing, not only higher yields are formed but also the productivity of a single plant.

In the studies conducted, the highest survival of chickpea crops and their density before harvest was in variants with pre-sown seed treatment with a mixture of *Rhizohumin* and Novofert and foliar nutrition of crops with Novofert during the branching phase. In particular, during three years of research, the density of plants in this variant was on average 65.2 pieces/m^2 with a survival rate of 76.7% (Fig. 1 and 2).

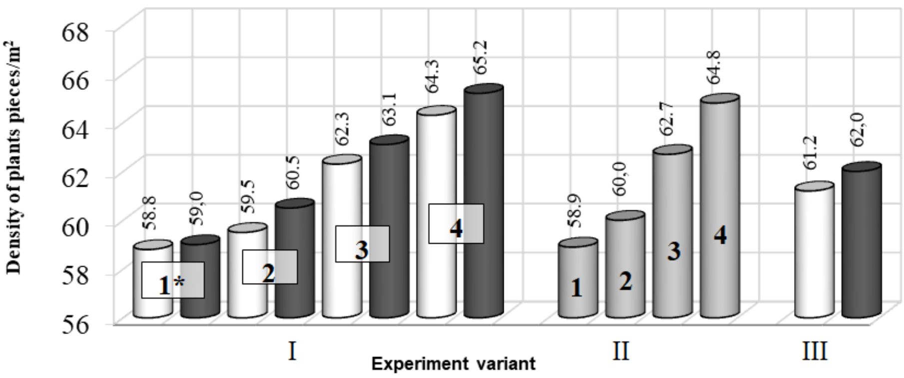
We should note that the combined application of Novofert and *Rhizohumin* preparations for the pre-sown seed treatment had a much higher efficiency in comparison with their separate use**.** On average, in terms of foliar nutrition variants, the density of plants before harvest in the joint application variants of these preparations was 4.8 pieces/m^2 higher compared to the variant in which seeds were treated only with Novofert and 2.1 pieces/m^2 more compared to the variant in which *Rhizohumin* (LED 05 factor A-1.9 pieces/m^2) was used only.

Theoretically, only because of the optimization of pre-sowing treatment of seed material, even under the same productivity as separate plants, the yield of chickpea grain will be higher by 10.0%.

The effect of foliar nutrition on the index variability of survival and plant density before harvest was much lower and was not statistically proven. In particular, the survival and density of plants before harvest on foliar nutrition variants compared to the control variant increased only by 1.0-1.5%. The primary task of nutrition is to remove stress from plants, improve their general state, and therefore increase their individual productivity.

The high efficiency of interaction of the factors studied is not determined. We found the increase in the efficiency of foliar nutrition in the variants of the presown seed treatment with one of the studied preparations or their mixture. For example, in the control variant of factor A (moisturizing of seeds with water), the nutrition of chickpea crops with Novofert compared to the control of factor B (treatment of plants with water) increased plant survival by only 0.2%, while in the variants of pre-sowing treatment of seeds with Novofert-by 1.0%.

The statement concerning forming higher elements of productivity in variants with higher survival indices and plant density before harvesting in the experiments aimed at studying the effectiveness of different variants of pre-sowing seed treatment and foliar nutrition has been confirmed in the conducted experiment. Therefore, the largest number of beans and grains in a chickpea plant on average by years is 20.6 and 22.8 pieces. Consequently, the variant with the highest survival indices and plant density before harvesting was observed, namely the variant with presown treatment of seeds with a mixture of *Rhizohumin* and Novofert (Fig. 3).



LED$_{05}$(AB) – 3.3 pieces/m^2; LED$_{05}$(A) – 1.9 pieces/m^2; LED$_{05}$(B) – 2.3 pieces/m^2

Fig. 1. Density of chickpea plants before harvesting depending upon seed treatment and foliar nutrition on average during 2018-2020, %.

Legend: Density of plants: I-by all experiment variants; II-by all variants of pre-sowing seeds treatment; III-by variants of foliar nutrition. Light columns-control of factor B (treatment of sown areas with water): dark-the second variant of factor B (nutrition of sown areas with preparation Novofert). Variants of seeds treatment: 1-control; 2 and 3-treatment with *Rhizohumin* and Novofert accordingly; 4-treatment with Novofert+*Rhizohumin*.

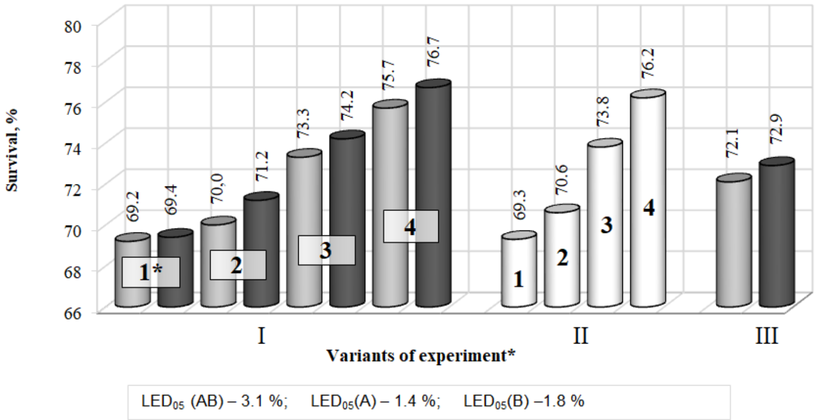


Fig. 2. Survival of chickpea plants depending on pre-sowing seed treatment and foliar nutrition on average during 2018-2020, %. Legend*:* Survival: I-by all variants of experiment; II-survival on average by variants of seed treatment; III-survival on average by all variants of foliar nutrition. Light columns-control of factor B (treatment of sown areas with water); dark-the second variant of factor B (nutrition of sown areas with preparation Novofert). Variants of seeds treatment: 1-control; 2 and 3-treatment with Novofert and *Rhizohumin* accordingly; 4-treatment with Novofert+*Rhizohumin*.

It follows that according to an important component of grain yield, agrocoenosis capacity, the advantage of the variant of presown seed treatment with a mixture of Novofert and *Rhizohumin* with further crop nutrition at the branching phase is much greater than by the indices of plant density before harvest, the number of beans and grains on one plant. In particular, the optimization of presown seed treatment and foliar nutrition with Novofert compared to the control has provided the increase in coenosis capacity by 16.1%, while the density of plants before harvest and the number of grains in one plant-by 10.9 and 4.6%, accordingly.

The statistically confirmed effect on the variability of the number of beans and grains in one plant only is peculiar for factor A-variants of pre-sowing seed treatment. The influence of foliar nutrition, as well as the effect of the interaction of the factors studied, is not statistically proven. In particular, in all variants of seed pre-sowing treatment, on average during three years of research, the number of beans and grains in a chickpea plant in variants with Novofert nutrition in the branching phase increased by 0.1 to 0.2 pieces. (0.5-1.0%).

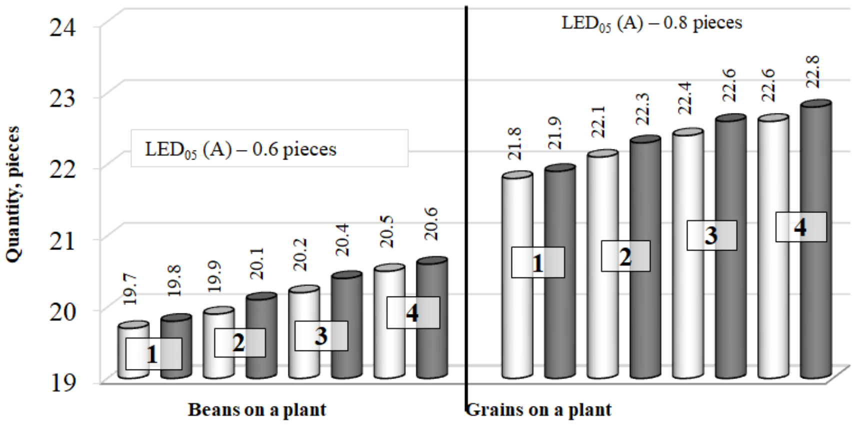


Fig. 3. Quantity of beans and grains on one chickpea plant depending on seed pre-sowing treatment and foliar nutrition on average during 2018-2020, %, pieces.

Legend: Light columns-control of factor B (treatment of sown areas with water); dark-the second variant of factor B (nutrition of sown areas with preparation Novofert). Variants of seed treatment: 1-control; 2 and 3-treatment with Novofert and *Rhizohumin* accordingly; 4-treatment with Novofert+*Rhizohumin*.

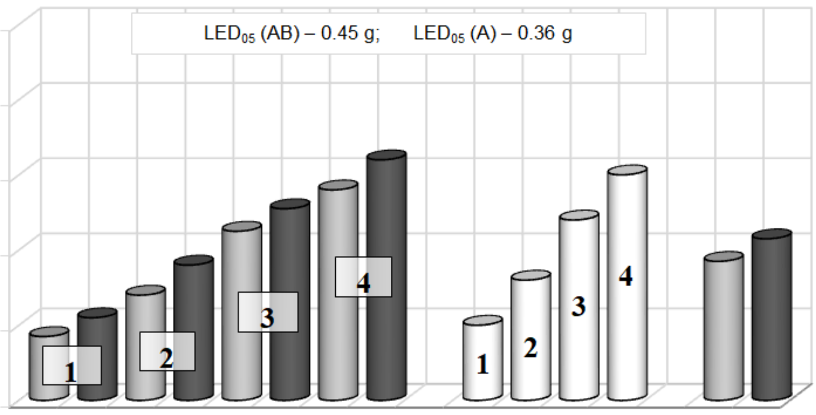


Fig. 4. Grain weight from one chickpea plant depending on pre-sowing seed treatment and foliar nutrition on average during 2018-2020,%, g.

Legend: I-grain weight by experiment variants; II-grain weight byvariants of seed treatment (factor A); III-grain weight on average by variants of foliar nutrition (factor B). Light columns-control of factor B (treatment of sown areas with water); dark-the second variant of factor B (nutrition of sown areas with preparation Novofert). Variants of seed treatment: 1-control; 2 and 3-treatment with Novofert and *Rhizohumin* accordingly; 4-treatment with Novofert+*Rhizohumin*.

The influence of the variants of seed treatment and nutrition studied on the variability of grain weight from one plant was slightly greater than on the number of beans and grains in one plant. In particular, on the variants of pre-sowing treatment of seeds with a mixture of *Rhizohumin* and Novofert followed by the next foliar nutrition with Novofert, the number of grains was on average 4.6% higher than *under* the control over three years, while their weight was larger by 6.8%. Indicates the formation of a higher mass of 1000 grains in these variants. At the same time, the mass of 1000 grains underwent much greater changes under the influence of weather conditions.

By analogy with the number of grains on one plant, its weight was the largest on the variant of pre-sowing seed treatment with a mixture of inoculant *Rhizohumin* and a complex fertilizer Novofert with foliar nutrition by this fertilizer during the branching phase. On average over three years, it amounted to 7.34 g, that was by 6.8% more than under the control (Fig. 4).

Among the variants studied for the presowing treatment of seeds, only the combined application of *Rhizohumin* and Novofert provided a significant increase in grain weight of one plant, the difference between other variants with the control was within LED_{05}.

As with the indicators of the number of beans and grains per plant, no significant effect of the studied variants of foliar nutrition on the variability of the indicators of grain weight of a chickpea plant has been observed ($F_f<F_t$).

The greatest changes under the factors influence of the studied factors were peculiar for the yield of chickpea grain, the final integral indicator determining the effectiveness of the application of certain variants of the constituent elements of cultivation technology. It is the indicator that can be used to define the agronomic efficiency of its application because in some cases certain advantages of specific structural elements may be leveled by others.

During three years, the highest chickpea grain yield in the experiment (4.31 t/ha) was observed in average on the variant of seed treatment with a mixture of *Rhizohumin* inoculant and Novofert complex fertilizer with foliar nutrition in the branching phase with this fertilizer (Table 1). Compared to the control, it has increased by almost 0.6 t/ha (16.0%).

Table 1. Distribution of chickpea grain yield indicators by groups based on statistical analysis using Duncan's ranking criterion on the basis of average data by years of research.

Seed Treatment (factor A)	Foliar Nutrition (factor B)	Grain Yield, t/ha	+/- Before Control, t/ha	Rank Group
Control (1)	Control (B)	3.73	-	1
	Novofert	3.76	+0.03	1
Novofert (2)	Control (B)	3.83	+0.10	1
	Novofert	3.88	+0.15	1
Rhizohumin (3)	Control (B)	4.12	+0.39	2
	Novofert	4.18	+0.45	2
Novofert+*Rhizohumin* (4)	Control (B)	4.24	+0.51	2
	Novofert	4.31	+0.58	3
Average by factor A	1	3.75	-	1
	2	3.86	+0.11	2
	3	4.15	+0.40	3
	4	4.28	+0.53	4
Average by factor B	Control (B)	3.98	-	1
	Novofert	4.03	+0.05	1

According to the statistical analysis based on Duncan's rank criterion, the grain yield got on this variant formed a separate rank group, i.e., it was significantly higher compared to the rest of the indicators obtained for other variants of the experiment.

Significantly higher yield compared with the control was also formed by the variants on which the pre-sown seed treatment with *Rhizohumin* was performed, as well as the control variant of factor B under the conditions of pre-sown seed treatment with a mixture of *Rhizohumin* and Novofert. The grain yields in these variants formed the second rank group.

The application of Novofert for presowing seed treatment without *Rhizohumin* did not provide a significant increase in grain yield. We observed only statistically the unproven tendency to index increase.

The analysis of factor A shows that all its studied variants formed separate statistically different rank groups, i.e., all of them varied significantly from each other. Following this, the variant of joint application of the *Rhizohumin* inoculant and the Novofert complex fertilizer for the presowing seed treatment has provided a significant increase in the yield of chickpea grain both compared to the control and with the variants of individual use of these preparations.

Examination of the factor B effect indicates the absence of a significant difference between its variants regarding grain yield indices. We established the factors effect of interacting the studied factors the difference between the variants of foliar nutrition studied by this indicator was greater on the variants of joint seed treatment with *Rhizohumin* and Novofert. In addition, a significant increase in grain yield was determined in the foliar nutrition variant with Novofert preparation in variants with seed pre-sowing treatment with a mixture of these preparations.

During all years of research, high efficiency of pre-sowing treatment of chickpea seeds with a mixture of *Rhizohumin* inoculant and Novofert complex fertilizer was observed. Only in 2018, we observed a significant increase in grain yield from the pre-sowing seed treatment with Novofert. In other years, there was only a trend of index growth in variants with presown seed treatment with this fertilizer (Table 2).

Table 2. Yield of chickpea grain under different variants of pre-sowing treatment of seeds and foliar nutrients, t/ha

Seed Treatment (factor A)	**Foliar Nutrition (factor B)**	**Year 2018**		**2019**		**2020**	
		I*	**II**	**I**	**II**	**I**	**II**
Control (1)	Control (B)	3.36	-	3.60	-	4.22	-
	Novofert	3.39	+0.03	3.64	+0.04	4.26	+0.04
Novofert (2)	Control (B)	3.48	+0.12	3.72	+0.12	4.30	+0.08
	Novofert	3.54	+0.18	3.76	+0.16	4.34	+0.12
Rhizohumin (3)	Control (B)	4.01	+0.65	3.90	+0.30	4.44	+0.22
	Novofert	4.08	+0.72	3.95	+0.35	4.49	+0.27
Novofert+*Rhizohumin* (4)	Control (B)	4.22	+0.86	3.96	+0.36	4.54	+0.32
	Novofert	4.32	+0.96	4.03	+0.43	4.59	+0.37
Average by factor A	1	3.38	-	3.62	-	4.24	-
	2	3.51	+0.13	3.74	+0.12	4.32	+0.08
	3	4.05	+0.67	3.93	+0.31	4.47	+0.23
	4	4.27	+0.89	4.00	+0.38	4.57	+0.33
Average by factor B	Control (B)	3.77	-	3.80	-	4.38	-
	Novofert	3.83	+0.06	3.85	+0.05	4.42	+0.04
Average of the experiment is		3.80		3.82		4.40	
LED_{05} (primary effect A)		0.11		0.14		0.17	
LED_{05} (primary effect B)		0.17		0.16		0.19	
LED_{05} (AB interaction)		0.25		0.22		0.28	

Note: I*-seed yield, t/ha; II-deviation from control, t/ha.

We should note that we observed a significant impact of weather on the efficiency of seed pre-sown treatment. In particular, in 2019 and 2020, the grain yield on the pre-sowing seed treatment variants with a mixture of preparations studied compared to the factor A control increased by 0.38 and 0.33 t/ha, while in 2018 it increased by almost 0.90 tons/ha. Despite the strength of the impact, the presowing treatment of seeds with a mixture of *Rhizohumin* and Novofert provided a significant increase in grain yield during all years.

Conclusion

Based on three-year studies, we have proved the high efficiency of application of *Rhizohumin* a mixture of inoculant *Rhizohumin* and complex fertilizer for pre-sowing treatment of chickpea seeds. We have marked the significant increase in the survival rates of chickpea plants in this variant in the experiments. The number of beans and grains, as well as the weight of grain from one plant, have also increased. In particular, compared to the control, the number and weight of grains of the plant on the variant of pre-sowing treatment of seeds with a mixture of these preparations were 4.1 and 5.7%, bigger on average over three years.

It should be emphasized that the optimization of chickpea cultivation technology because of pre-sowing seed treatment with a mixture of inoculant *Rhizohumin* with Novofert complex fertilizer, followed by foliar nutrition with this fertilizer during the flowering phase, provides a significant increase in grain yield. In years with different vegetation weather, grain yield in this variant was 0.37

to 0.96 t/ha higher than in the control. Providing growth improvement and development of plants and a significant increase in grain yield, the application of these preparations is ecologically safe and economic and does not involve significant additional costs.

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