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ORIGINAL ARTICLE

Agroecological methods of improving the productivity of niche leguminous crops

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It is presented the results of field investigations from study the effect of pre-sowing seeds treatment by inoculants and foliar fertilizing by complex fertilizers on the peas and chickpeas cultivations. It is elaborated new science-technology methods of leguminous crops growing, on an example of peas and chickpeas to stabilize agricultural production, what will give the opportunity to estimate the efficiency of bean-rhizobia symbiosis under applying of different strain inoculants adaptive to this kind of crops and complex fertilizers with content of macro-and micronutrients for foliar fertilizing.
The results of study the efficiency of combine use of bacterial preparations, such as Rizoline and Groundfix on the mineral fertilizing background $N_{30}P_{60}K_{60}$ on the pea's genders, and also applying double foliar fertilizing by complex fertilizers and insecticide-fungicide preparation in the phases of three true leaves and budding are presented in this article. The most favorable conditions for chickpeas yield formation are drawn up under applying seeds inoculation and two foliar fertilizations in the intensive grow phase and budding phase, the average yield index in 2016-2017 years on this variant was obtained 2.76 t/ha.
Keywords: Peas; chickpeas; snap beans; seed treatment; inoculant; microfertilizers; yield; biological nitrogen; tuberous bacteria

Introduction

National strategy for development of agroindustrial complex of Ukraine prognosticates the development of leguminous crops market as a source of valuable vegetative protein with content of irreplaceable range sulfur-containing aminoacids. Annual leguminous crops, which are one of the best sources of high-quality, balanced by aminoacids content, cheap and ecology safe protein occupy an important place in the vegetable food protein resources. Recently the problem of world's population needs fulfilling in protein food becomes increasingly actual recently. The grain of legume crops has high protein content, and also these plants act as soil fertility enhancers due to its ability to nitrogen fixation, what is valuable and very important when in the structure of sown areas there is an advantage of monoculture (Kyjenko, 2016).
Such scientists, as V.F. Petrychenko, V.P. Patyka, O.A. Babych, S.M. Kalenska, S.I. Kolisnyk, M.Ya. Shevnikov, S.Ya. Kots, V.V. Volkohon, V.F. Kaminskyi V.F., O.M. Bakhmat, A. Scwartz, E. A. Elsheikh, G. S. Tagore, A. C. Mishra and others dedicated their works for questions of finding the high-productivity bean-rhizobia systems formation, which would provide significant increasing of productivity through justification the peculiarities of plant grow and development, combination of leguminous crops nitrogen-fixing capacity, elaborate and implementation of bio-organic methods of growing.
Nowadays a lot of leguminous crops kinds haven't lose its mean as important food crops and take a leading place in the formation of food and protein resources in many countries of the world. In recent years the demand on the legumes crops has quickly increasing in Ukraine and in the world. The proclamation by the General Assembly UN 2016 as the International Year of Legumes contributes to this. Within the framework of this event, is accepted and approved by Ministry of Agrarian Policy and Food of Ukraine "The development program of peas, chickpeas, lentils and beans cultivations in Ukraine" and agrarian sector strategy development "3+5" in Ukraine. One of the main directions of this strategy is the development of organic agriculture and production of "niche" crops. They include the rare leguminous crops: peas, edible lentils, common chickpeas, grass peas, beans etc.
However, the expressed tendencies to climate change, formation of alternative fertilization systems in growing technology of base agricultural crops, world's strategy on biology technological providing for obtaining of vegetable protein require a search

of effective especially bioorganic systems in potential realization of main leguminous crops in the system of symbiotic interaction by plants mycorrhiza and selected biopreparations of different origin (stimulants, strengthens of nitrogen fixation etc.), with searching of optimal models for connection of this approach and complex of modern chelates microfertilizers.

New method of bacterial preparation applying will improve the processes of symbiotic interaction among plant and rhizospheres' microflora. The application of high-effective strains of tuber bacteria in the symbiosis of modern legume crops varieties will allow to increasing the productivity by plants till 10-30% and enhancing the grain protein content on 2-6%, and 1-3% in green mass (Ghamajunova & Nazarchuk, 2014; Shherbakova, 2016; Krutylo, Ushakova & Kolisnyk, 2015).

More and more attention is given to biogenic fixation by legumes cultures of atmospheric nitrogen, as a powerful factor for soils fertility support, nitrogen fertilizer saving and environmental safety in modern agriculture (Petrychenko & Kocj, 2014). One of the directions of biological agriculture is applying of microbiological preparations, created on the nitrogen fixation and phosphate-mobilizing bacteria foundation, growth regulators and bio-protective microorganisms (Volkoghon & Kozar, 2015).

The activation of plant-microbial interaction is a powerful factor in increasing the productivity of agrocenosis, but it is used inappropriately in agricultural practice. Therefore, it is necessary to massive using of ecologically advisable technologies with application of microbial preparations, which is important perspective to high-quality competitive agricultural production obtaining, soils fertility and environmental preservation.

Biopreparations are more effective in conditions of agrofon, which is optimized by meloirants, organic and mineral fertilizers applying. Thereby, there are all reasons to confirm that requirement in microbial preparations of soils fertilizing action will be increasing from year to year, considering as on the large agricultural areas in Ukraine, so on the trends of biopreparations applying in agriculture of other countries. Because the microbial preparations applying in growing technologies of agricultural crops contributes to nutrition optimization and provides those protection against pathogenic microflora, which allows to mostly realize the potential of agricultural production (Patyka, et al., 2015; Vdovenko, et al., 2018). The investigations of scientific institutions confirm the necessity of field crops foliar fertilization by complex fertilizers with content of stimulants, aminoacids, and micronutrients. However, these agro-technical methods cause still a lot of questions, therefore it is necessity to development of mineral nutrition optimization for leguminous crops, systematization of interaction between the microbiological and complex fertilizers on the symbiotic and photosynthetic systems development, yield increasing and its quality with recommendations for agricultural producers (Volkoghon & Kozar, 2015; Patyka, et al., 2015; Vdovenko, et al., 2018; Petrychenko, et al., 2018).

One of the increasing productivity and yield quality factors in technological processes of agricultural crops growing is applying of micronutrients (Artementko, et al., 2015). The deficiency of micronutrients in the soil can lead to diseases and even become the reason of plants destruction. It is proven by the newest researchers, that there is roots nutrition next to the airy. It allows optimizing the plants nutrition by macro-and microelements in some vegetation periods and eventually increase the yield and improve the quality of plant production (Telekalo, 2014; Victor, et al., 2018; Didur & Mordvanjuk, 2018; Maureen, 2016).

Materials and methodology of researches

The aim of research is exploring the symbiotic productivity and yield of peas and chickpeas varieties depending on the effect of agro-ecological methods under conditions of right-bank Foreststeppe.

The investigations were conducted during 2016-2017 years in field crop rotation of the department of plant production, breeding and bioenergy crops Vinnytsia National Agrarian University. On the gray forest medium loam soils with humus content in the arable layer 2.11%. The reaction of soil solution pHsalty-5.4, hydrolytic acidity of 3.7 mg eq./100 g soil, the sum of absorbed bases 18.7 mg eq./100 g soil. The content of easily hydrolyzed nitrogen-6.9 mg eq./100 g soil, mobile forms of phosphorus and exchangeable potassium-10.8 and 8.3 mg eq./100 g soil respectively. A multifactorial field experiment was conducted on pea's cultivations to solve the set tasks (Table 1).

Table 1. The scheme of research.

Factors A-variety	Factors B-Presowing seeds treatment	Factors C-System of defense and nutrition
1. Ataman	1. Without treatment.	1. Without treatment.
2. Gregor	2. Rizoline	2. $N_{30}P_{60}K_{60}$ (Background).
	3. Groundfix	3. Background+the phase of third real leaves-“Gumat-list”(1 l/ha)+“Lf-ultrafit”(5 l/ha) .
	4. Rizoline+Groundfix	4. Background+the phase of budding “Gumat-list” (1 l/ha)+“Lf-ultrafit” (5 l/ha)+“Lf-Bobovi” (2 l/ha)+“Lf-Bor” (1 l/ha).
		5. Background+he phase of third real leaves and the phase of budding.

The predecessor crop of peas was spring barley in crop rotation. The research of three factors: A-variety; B-system of defence and nutrition; C-presowing seeds treatment. The ratio of these factors is 2 × 5 × 4. The repeatability is fourfold in the experiment; the placement of variants is systematic in two tiers.

It was elected two pea's varieties; one of domestic selection (The Plant Production Institute nd. a. V. Ya. Yuryev of National Academy of Agrarian Sciences of Ukraine): Ataman (2011 yr.) and Gregor is the variety of foreign selection (Germany). The seed rate was 1.2 million pcs. viable seeds on 1 ha.

Inoculation was conducted by biological preparations on the day of sowing. For seed bacteriation were used the Rizoline (Rhizobium leguminosarum) in the rate of 3 l/ha and Groundfix (Bacillus subtilis, Bacillus megaterium var. phosphaticum, Paenibacillus polymyxa KB) in the rate of 2 l/ha.

Foliar fertilizations were carrying out by cistern mixtures in the phases of 3 true leaves and budding, according to the research scheme.

The system of defence and nutrition were carried out by soluble complex fertilizers “Gumat-list” at a dose 1 l/ha and “Lf-ultrafit” at a dose of 5 l/ha (insecto-fungicidal bacterial preparation based on two strains of microorganisms Pseudomonas aureofeciens. The preparation has two bacterial strains: one is using against the fungal diseases, another-against the pests) and “Lf-Bobovi”, which contains macro-and micronutrients (N-44.0-48.0 g/l; P2O5-50.0-52.0 g/l; K2O-52.0-55.0 g/l; B-3.5-4.0 g/l; Cu-6.0-6.5 g/l; Fe-7.0-7.6 g/l; Mn-5.5-6.0 g/l; Mo-1.9 g/l; Zn-7.0-7.6 g/l; S-81.0 g/l; Co-0.03-0.05 г/л; Ni-0.006 g/l and “Lf-Bor” (B-140-141 g/l; N-62-650 g/l; Mo-05-0.1 g/l.

The investigations of chickpeas cultivation were conducted on the research field of VNAU in Ahronomichne village in Vinnytsia region during 2016-2017 yr. The soil of experimental field is gray forest. There was variety Pegas used for investigation. The seed rate is 600 thou. pcs. ha. The research scheme is: factor A-seed treatment: 1) control (without inoculation), 2) inoculation by Biomag chickpeas (350 ml on 1 ha seed rate); factor B-foliar fertilization: 1) (control)-without fertilization, 2) 1 fertilization (intensive growth phase-2 l/ha), 3) 2 fertilizations (microfertilizer Urozhai Bobovi, intensive growth phase+budding phase-2 l/ha).

Researches on the study of the symbiotic potential of snap beans in the variety Zironka, depending on the biological preparation, were conducted in 2016-2017 on the experimental field of the Vinnytsia National Agrarian University. The soil of the studied field is gray forest, medium loamy. The seed rate is 400 thousand pieces / ha. The trial has 4 variants, the repetition of the experiment is four-time. The research scheme is: 1. without pre-planting treatment (control version); 2. pre-sowing treatment with biological preparation Azotophyte-l; 3. pre-sowing processing Biomag biological preparation; 4. pre-sowing treatment with a biological preparation Biocomplex-BTU-l. Before sowing, the seeds of the control variant were treated with water.

Results of research and their discussion

The determination of the symbiotic fixation magnitude of nitrogen by planting peas was carried out by taking into account the number and weight of nodules on the root system of plants.

There were some changes has got the indexes of symbiotic activity level of peas cultivations depending on the pre-sowing seed treatment and defense system and nutrition, as the results show. The total nodules amount and mass of Ataman pea variety was 60.4 pcs. per plant or 302.0 kg/ha in the phase of full blooming on the background of N30P60K60 fertilization with connection between the pre-sowing seed treatment by Rizoline and Groundfix. The fertilizers applying was increased the amount of roots nodules on 10.5-12.6% in comparison with control (26.4 pcs./plant). Herewith the general amount of nodules mass was bigger on 23.4-38.9% in comparison to control (99.7 kg/ha). The maximum nodules mass of Gregor variety was noticed in the phase of full blooming-170.6-410.5 kg/ha.

The mass of active nodules was increasing till full blooming phase, had achieving the maximum and had been 233.3 kg/ha of Ataman variety on the experiment variants where pre-sowing seed treatment and foliar fertilizers on the N30P60K60 background fertilizing were used. After that the rhizobial activity of peas cultivations was reducing and the nodules mass had been declined almost to half in the phase of seed filling. The outflow of plastic substances to reproductive organs has been reduced the root nutrients providing, which are necessary for viability and nitrogen fixation ability maintenance of nodules bacteria. However, the functional process of root's nodules of peas activated with adding the foliar fertilization by «Lf-Bobovi» and «Lf-Bor» in the phase of budding, the activity of nodules was saved till physiological maturation. The development of symbiotic organ of Gregor variety was similar to Ataman variety, but the indexes of active nodules mass (328.7 kg/ha) were bigger on 20.8-57.7%.

The considerable indicator of legumes-rhizobial symbiosis working during the vegetation period is admeasurement of general (GSP) and active symbiosis potentials (ASP), which determines in kg/ha of nodules tissue multiplied on the life duration in days (kg*daily/ha). The general symbiosis potential shows an all mass of root's nodules during an all their life period, the active symbiosis potential shows only the mass of root's nodules with leghemoglobin and duration of active symbiosis, to wit the time period from leghemoglobin formation in the nodules till its switchover to choleglobin.

The results of conducted research show that the size of GSP and ASP has changed unequally and has got sinusoidal character during the vegetation period. General and active symbiosis potentials of peas has gradually increased, beginning from the nodules period emergence-7th leaf till full blooming-seed filling period. And subsequently there is gradual reduction of quantity and weight of root's nodules, respectively the symbiosis potentials too.

The positive nitrogen balance is noted on all the experiment variants, but the biggest its amount was stayed not on the variants with maximum nitrogen fixation from air. The maximum indexes of atmospheric nitrogen fixation of Ataman variety 79.0 kg/ha and Gregor variety 121.6 kg/ha were accumulated on the variant, where pre-sowing seed material treatment by bacteria complex (Rizoline+Groundfix) were conducted and the foliar fertilizers in the phase of 3 true leaves by Humat Lyst (1 l/ha)+Ultrafit (5 l/ha) and in the budding phase-Humat Lyst (1l/ha)+Ultrafit (5 l/ha)+LF-Bobovi (2 l/ha)+LF-Bor 140 (1 l/ha) were applied on the background of $N_{30}P_{60}K_{60}$ fertilizing, while with the harvest was removed 174.1 kg/ha (Figure 1).

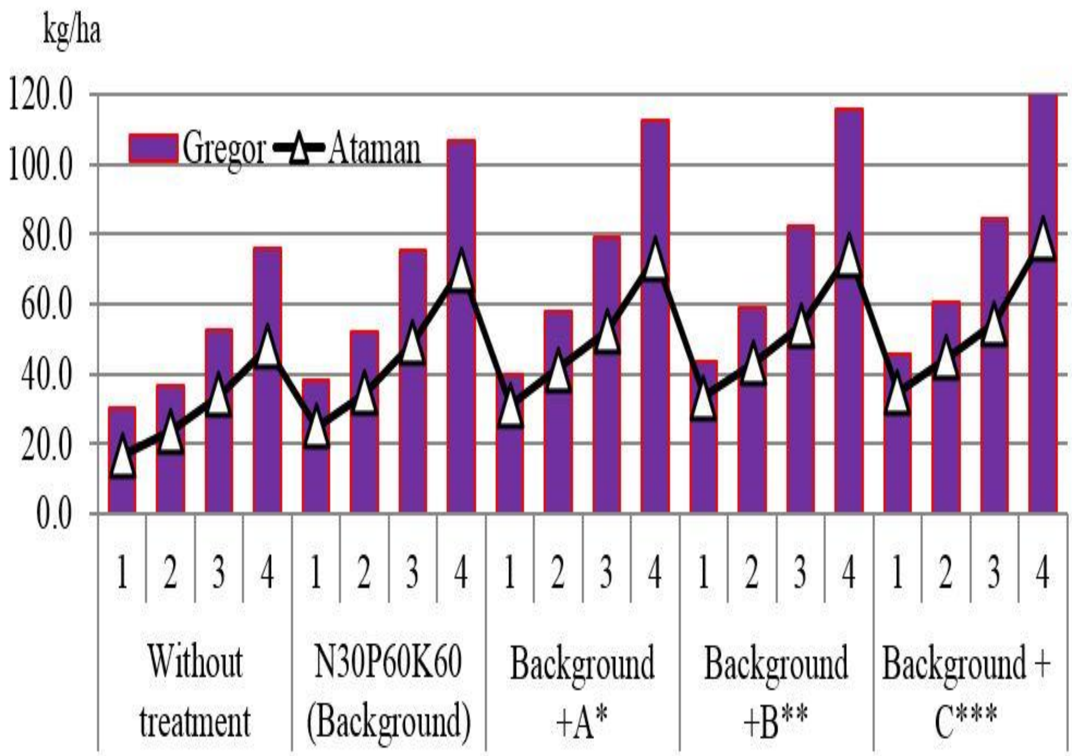

Figure 1. The accumulation of biologically-fixed atmospheric nitrogen by pea's cultivations, kg/ha (on average 2016-2017 yr.).
Note:* 1-Without treatment; 2-Rizoline; 3-Groundfix; 4-Rizoline+Groundfix; A*-the phase of third real leaves-“Gumat-list”+“Lf-ultrafit”; B**-the phase of budding “Gumat-list”+“Lf-ultrafit”+“Lf-Bobovi”+“Lf-Bor”; C***-A+B.

The ability of legumes crops to accumulation of considerable amount of protein in the yield is closely related to its exceptional peculiarity to form the symbiosis with nodules bacteria.

There are some changes has received the quantitative indexes of symbiotic activity of cultivations, in particular the amount and weight of nodules on the chickpeas cultivations, depending the pre-sowing seed treatment by inoculant Biomag chickpeas and foliar fertilizing by microfertilizer Urozhai Bobovi, in the investigations process (Table 2).

Table 2. The dynamics of root's nodules amount and weight of chickpeas plants depending the seed inoculation and foliar fertilization, (on average 2016-2017 yrs).

Inoculation	Foliar fertilization	Budding		The beginning of blooming		The end of blooming		The full seeds ripening	
		Amount of nodules, pcs./plant	Weight of nodules, mg./plant	Amount of nodules, pcs./plant	Weight of nodules, mg./plant	Amount of nodules, pcs./plant	Weight of nodules, mg./plant	Amount of nodules, pcs./plant	Weight of nodules, mg./plant
Without inoculation (control)	Without fertilization	7.4	46.1	17.3	176.4	24.3	403.5	17.3	109.7
	1 fertilization*	9.9	48.4	21.7	201.9	29.5	527.7	22.5	131.3
	2 fertilizations **	10.5	53.9	25.1	224.5	32.6	554.7	24.1	145.7
Biomag chickpeas (350 ml. on ha. r. seed)	Without fertilization	11.1	62.6	25.7	234.3	34.7	568.6	25.4	149.7
	1 fertilization*	11.5	64.8	26.5	243.4	35.8	586.3	26.7	151.6

2 fertilizations **	12.1	68.9	31.8	251.2	38.7	603.6	28.3	162.4

The investigation results testify about reliable peas yield increasing when pre-sowing seed treatment by bio-preparations is applying. The using of bacteria (Rizoline) in the composition with Groundfix has increased the pea's grain yield of Ataman variety on 0.34 t/ha (2.70 t/ha), with main fertilizing applying N30P60K60 the magnification was 1.38 t/ha and the efficiency of pre-sowing seed treatment was increasing till 1.62-1.84 t/ha, which was set 58.5% and 68.4-78.0% in comparison with control-2.36 t/ha, when foliar fertilizing was applying. The yield increment of Gregor variety was 0.33 t/ha when using seed inoculation by Rizoline+Groundfix, this index was 1.11 t/ha when main fertilization had been used and foliar fertilization had increased the yield on 1.30-1.87 t/ha (Table 3).

Table 3. Grain yield of peas depending on the impact of presowing seeds treatment and system of defence and nutrition, t/ha, average 2016-2017.

System of defence and nutrition	**Presowing seeds treatment**			
	Without treatment	**Rizoline**	**Groundfix**	**Rizoline+Groundfix**
Variety Ataman				
Without treatment	2.36	2.4	2.52	2.7
$N_{30}P_{60}K_{60}$ (Background)	3.31	3.4	3.51	3.74
Background+A*	3.52	3.65	3.75	4.01
Background+B**	3.51	3.68	3.77	3.98
Background+C***	3.66	3.78	4.04	4.2
Variety Gregor				
Without treatment	2.75	2.84	2.97	3.08
$N_{30}P_{60}K_{60}$ (Background)	3.42	3.5	3.66	3.86
Background+A*	3.65	3.88	3.92	4.05
Background+B**	3.8	3.95	4.1	4.28
Background+C***	4	4.2	4.36	4.62

Note:* A*-the phase of third real leaves-"Gumat-list"+"Lf-ultrafit"; B**-the phase of budding "Gumat-list"+"Lf-ultrafit"+"Lf-Bobovi"+"Lf-Bor"; C***-A+B. HIP 0,05 t/ha; A-Variety; B-presowing seeds treatment; C-system of defence and nutrition. 2016-2017 years. A-0.24; B-0.27; C-0.07; AB-0.45; AC-0.42; BC-0.59; ABC-0.86

The maximum yield of peas variety Ataman-4.20 t/ha and Gregor variety-4.62 t/ha formed after pre-sowing seed treatment by Rizoline+Groundfix and foliar fertilizing in the phase of 3 true leaves by Gumat-list (1 l/ha)+Ultrafit (5 l/ha) and in the budding phase by Gumat-list (1 l/ha)+Ultrafit (5 l/ha)+Lf-Bobovi (2 l/ha)+Lf-Bor (1 l/ha) on the N30P60K60 fertilizing background, what is respectively bigger on 1.84-1.96 t/ha in comparison with control.

The significant influence of pre-sowing seed treatment by inoculant Biomag chickpeas and foliar fertilizers by microfertilizer Urozhai Bobovi was noted on the chickpeas grain yield formation in the course of research (Table 4).

The chickpeas yield in 2016 on the variant without inoculation (control) and with two foliar fertilizations was inferior on 0.62 t/ha in comparison with this index of 2017, what can be seen from the table leaded upon. On the variant, where pre-sowing seed treatment by inoculant Biomag chickpeas and double foliar fertilization by microfertilizer Urozhai bobovi were used, this index was equal 2.42 t/ha in 2016, which is under on 0.68 t/ha in comparison with this index in 2017 yr.

The chickpeas grain yield increasing was observed from conducting of pre-sowing seed treatment by inoculant and two foliar fertilizations, thus in 2016 yr. on this variant were got 2.42 t/ha, which was bigger on 0.61 t/ha in comparison with the control (without inoculations and foliar fertilizations), the similar data in the same variant were obtained in 2017 yr.-3.1 t/ha, which was bigger on 1.12 t/ha, respectively to control.

Table 4. The yield of chickpeas grain depending the seeds inoculation and foliar fertilization, t/ha (on average 2016-2017 yrs).

Inoculation	**Foliar fertilization**	**Grain yield, t/ha**		**Average grain yield, t/ha**	**The increment of grain yield, t/ha**
		2016 yr.	**2017 yr.**		
Without inoculation (control)	Without fertilization	1.81	1.98	1.9	-
	1 fertilization*	2.14	2.36	2.25	0.35
	2 fertilizations**	2.22	2.84	2.53	0.63
Biomag chickpeas	Without	1.84	2.56	2.2	0.3

	fertilization				
(350 ml. on ha. r. seed)	1 fertilization*	2.19	2.71	2.45	0.55
	2 fertilizations**	2.42	3.1	2.76	0.86

Note: *-the intensive growth phase, microfertilizer Urozhai bobovi, 2 l/ha; **-the intensive growth phase+budding phase, microfertilizer Urozhai bobovi, 2 l/ha.

Therefore, the obtained results in respect of chickpeas yield depends the pre-sowing seed treatment by inoculant Biomag chickpeas and foliar fertilizations by organic microfertilizer Urozhai bobovi give reasons to conclude that the most favorable conditions for plant growth and development, and grain yield formation for chickpeas cultivation are receiving when seed inoculation and two foliar fertilization in the phase of intensive growth and budding phase are using, the yield index on average 2016-2017 yrs. was 2.76 t/ha on this variant. The increment to the control was 0.86 t/ha respectively on this variant (Table 5).

During the period of conducting field research on snap bean seeds of the variety Zironka, the influence of seed inoculation on the formation of the yield of bean spatulas and the formation of tubers on the root system of the plant.

Table 5. Effictiveness of symbiotic productivity and yield of snap beans (*Phaseolus vulgaris* L.) depending on the use of biopreparation, Zironka variety (average for 2016-2017 years).

Variant	**The number of tubers, pc./plant phase of mass bloom**	**Mass of tubers, mg/plant**	**The yield, t/ha**	**± before the control**	
				t/ha	**%**
Without pre-sowing cultivation (C*)	19.2	231	16.1	-	100
Azotophyte-l	23.6	484.2	21	4.6	130.4
Biomag	21.1	353.1	21.1	5	131.1
Biocomplex-BTU-l	28.5	622.4	29.1	13	180.7
NIR_{05}	-	-	0.91	-	-

Note: C*-Control.

From Table 5 it can be seen that the maximum value of yield was obtained on the variants of the experiment where the Biocomplex-BTU-l was used. At the same time, the yield was 29.1 t/ha and exceeded the control version by 13.0 t/ha.

Indicators such as the number of tubers and the mass of tubers were also affected by yield levels. In the phase of mass bloom, the largest number and weight of tubers were formed on the variant with the use of biopreparation Biocomplex-BTU-l-28.5 pc./plant and 622.4 mg/plant, which was 9.3 pc./plant and 391.4 mg/plant more variant without pre-planting treatment, respectively.

The Biomag biopreparation contributed to the formation of the smallest amount and weight of tubers-21.1 pc./plant and 353.1 mg/plant, however, we received higher values relative to the control variant for 1.9 pc./plant and 122.1 mg/plant, respectively.

Conclusion

The biggest amount of biologically fixed nitrogen was obtained by peas varieties on the variant with simultaneously using of pre-sowing seed treatment by Rizoline and Groundfix and foliar fertilization in the phases of 3 true leaves and budding on the mineral fertilization background $N_{40}P_{60}K_{60}$-79.0 kg/ha of Ataman variety and 121.6 kg/ha of Gregor variety. The maximum peas yield of Ataman variety 4.20 t/ha and Gregor variety 4.62 t/ha was obtained on the same variant.

The culminant indexes of nodules formation on the chickpeas cultivations-38.7 pcs./plant and their weight 603.6 mg/plant were obtained at the end of flowering, which would provide the highest yield-2.76 t/ha of Pegas variety.

According to the results of the research, it was established that the amount of accumulation of biological nitrogen and the formation of a relatively high yield of bean spatulas snap beans are the influence of the soil-climatic conditions of the years of research and application of the bacterial preparation Biocomplex-BTU-l.

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