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Influence of Nitrogen, Phosphorous, Potassium Fertilizers and Inoculants on Formation of Vegetative Organs, Amount of Nodules and Yield of Soybean Cultivars

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Abstract: In the article, the results of experiments on the effect of different inoculants on the development of soybean growth, yield, grain quality, and the amount of nitrogen, phosphorus, and potassium in the vegetative organs of the plant during the podding phase, when the new Es-mentor varieties of soybeans created in Krasnodar regions and the local Orzu were planted as a repeat crop after the autumn wheat harvest stated. *Bradyrhizobium japonicum Bacillus subtilis BS-26* created in our republic in the conditions of irrigated typical gray sierozem soils of Tashkent region and complex inoculant imported from the Russian Federation contains 3-Ligabak pronok (*Bradyrhizobium japonicum* (109), *Bradyrhizobium diazoefficiens* (USDA110), *Bradyrhizobium elkanii* (E123)+0.5% molybdenum. The results of the study on the effect of the added bacteria on the yield and quality of the soybeans were analyzed in the section of experimental options. The soybean varieties were planted at a rate of 700,000 seeds/ha with a row spacing of 70 cm. Es-mentor variety (1000 1000 seed mass 190 g) 103 kg/ha,Orzu variety (1000 seed mass 130 g) 91 kg/ha of seeds were used, the difference in seed consumption in kilograms was caused by the difference in the mass of 1000 seeds, the number of seeds sown was the same in both varieties. 700 thousand seeds/ha effected the results of the experiment on the quality of the harvest are described.

Keywords: Dream, Es-mentor, protein, inoculant, budding bacteria, yield, grain, soybean, crop quality, oil, nitrogen, phosphorus, potassium, anguz, gray soils.

1. Introduction

In our republic, in recent years, it is important to make good use of areas that have been harvested from grain crops, to grow a second crop, to increase soil fertility, to grow high-quality valuable grain crops, including soybean, and to produce a high yield with the effective use of regional bioclimatic resources.
Soybean crop among legumes is a valuable crop to increase soil fertility that accumulates a lot of nitrogen during the season, and has a lot of protein and oil in its seeds (2, 5).
The soil and climatic conditions of Uzbekistan provide an opportunity to plant and harvest several different crops per year, with the effective use of irrigated land. The high temperature that lasts from mid-May to the end of September is very favorable for the growth of heat-loving crops (soybeans, mung beans, etc.) and grain formation (4, 5).
Soybean is a biologically clean crop that improves soil structure and activates biological processes. Analysis shows that 0.65-0.72% humus in the soil before soybean planting reaches 0.95-1.03% after soybean planting (4).
In recent years, in addition to organic, mineral and green fertilizers, bacterial fertilizers and inoculants have been widely used in agriculture to increase the yield of leguminous crops, including soybean has taken research results in various sources on how to make, collect, absorb, satisfy the plant's need for nitrogen up to 50-70% and increase soil fertility, improve water-physical properties, drastically reduce the use of nitrogen fertilizers (7, 8, 9, 10, 11, 12).
Kh.N. Atabaeva., F.B. Namozov., A.A. Kurbanov and S.Sh. Khayrullaev in their experiments conducted in 2018-2020, when they applied micronutrients to the soybean crop, micronutrients affected the height of the

soybean stem, leaf, root development, nodule formation, grain quality and productivity, and provided a high yield [10].

According to R. Jo'raeva., J. Toshpol'atov., A. Iminov., Kh. Bozorov and L. Zaynitdinova, S. Khatamov and S. Sh. Khayrullaev, in their experiments conducted in 2015-2017, soybean plant mineral fertilizers and belonging to the rhizobium group it was observed that the yield increased by 12.6-12.8 c/ha when exposed to azotobacteria strains compared to the control variant [11, 14].

According to Khayrullayev Sardor Shamsiddin ugli (2021), the application of micronutrients in the suspension method 2 times during the application period of soybean varieties in the conditions of meadow-swamp soils provides an increase in grain quality [16]. According to data of Atabayeva Khalima Nazarovna, Khayrullaev Sardor Shamsiddin o'g'li, and Usmonova Shohista Usmon qizi (2020), sulfur has a positive effect on the branching of soybean varieties on the background of mineral fertilizers, and in 2018 the number of branches in the variety "Orzu" increased by 0.8-1.3 compared to the control option due to the micro element sulfur. In the "Nafis" variety, this figure was 0.3-0.4, and good results were obtained from medium and high sulfur standards. In 2019, these indicators increased by 0.3-0.7 in the variants of sulfur compared to the control in the "Orzu" variety, increased by 0.1-0.3 in the "Nafis" variety, and good results were obtained from the medium and high standards of sulfur [13]. According to Iminov Abduvali Abdumannobovich, Khayrullayev Sardor Shamsiddin ugli, et al, Nitragine treatment of soybean and mung bean seeds before sowing had a positive effect on seed germination under both laboratory and field conditions, the germination rate of seeds in the laboratory under the conditions of cotton cultivation in the following year under the background of non-treatment by nitragine before sowing the seeds of soybean and mungbean crops grown as a secondary crop after winter wheat was 0.3-1.3%, and field fertility was 0.2-0.8% higher. Also, it was found that the use of phosphorus and potassium fertilizers in soybean and mung bean crops grown as a secondary crop was 0.6-1.0% higher in the laboratory, and 0.6-0.7% higher in the field than in the control options without mineral fertilizers in studies [12]. According to Umarova Nigora Sadriddinovna, Bo'riboyev Bekzod Yetmish ugli, Khayrullayev Sardor Shamsiddin ugli, Usmonova Shokhista Usmon kizi, & Turdaliyeva Shokhista Tulkinjon kizi, the demand of the soybean plant for mineral fertilizers, it was observed that when NPK and liquid fertilizer were used together, all the biometric parameters and yields of the plant increased by varieties compared to other methods. The use of mineral fertilizers in different ways in typical sierozem soil conditions affects the grain yield of local and foreign varieties. In other words, the average yield of medium-ripe soybean varieties "Nafis" was 43.4 c / ha, "Vilana" was 42.4 c / ha, and the best way to increase the yield is to apply fertilizers as NPK in combination with liquid fertilizer [17]. According to data of Khayrullayev Sardor Shamsiddin o'g'li and Usmonova Shohista Usmon qizi, the location of the lower first pod in soybean varieties is 12.8-15.9 cm in Orzu variety, 3-3.1 cm in Radimax stimulator, 2.2-2.4 cm in Gummat stimulator, 2.1 cm in Tecamin stimulator and 3.1 cm in Algora stimulator was found to be high. The most effective results were observed in Radimax, Gummat and Algora bio-simulators, and the location of the lower first pod was detected 14.7-17.6 cm in the "Nafis" variety, which was 2.5-2.9 cm higher in the Radimax stimulator, 2.2-2.5 cm higher in the Gummat stimulator, 2.1 cm higher in the Tecamine stimulator, and 2.4 cm higher in the Algora stimulator than in the control variant. The most effective results were observed in Radimax, Gummat and Algora biosimulators [15]. According to Atabayeva, K. N., Umarova, N. S., Yakubov, S., & Khayrullaev, S. S, positive results were obtained from moderate levels of sulphur and manganese, and low levels of iron. Macro and micronutrients had a positive effect on soy yield. An additional 7.6 quintals (q)/ha was harvested in exchange for macro fertilizer. Compared to the background variant, the yield was 4.6-8.3 q/ha for sulphur and 4.9-9.8 q/ha for manganese. The yield of the iron element was lower than that of the background variant. Grain quality has changed in exchange for macro and micronutrients. In exchange for mineral fertilizers, this figure increased by 2.4%. In exchange for the element sulphur, the protein increased by 3.1-5.8%; an increase of 4.4-8.4% was observed in exchange for the element manganese. It was noted that the protein increased by 7.9-8.7% in exchange for the element iron [18]. Khayrullayev, S. S., & Kizi Usmonova, S. U explained that mineral fertilizers and sulfur microelements activate the symbiotic activity of soybean variety "Orzu", averaging 32.4-42.3 million nodules per hectare, the number of nodules due to the background of mineral fertilizers increased by 13.6%, and there was an increase of 19.4-23,4% due to sulfur, as well as an average weight of nodules was 6.46-9.56 c / ha, the weight of nodules increased by 5.3% due to mineral fertilizers, and 17.1-32.4% due to sulfur. During the application period, 6.46-9.56 c / ha of nodules mass was accumulated per hectare according to the studied variants, which contributes to the increase of nitrogen and organic matter in the soil and a slight increase in biological efficiency [19]. Usmonova Sh.U, Khayrullaev S.Sh, Shomuqimov N.N, & Gaynanova A.F, said that the influence of stimulants on soybeans affected the weight of 1000 grains of Vilana cultivar, under the influence of Gummat stimulator this figure was 2.2-7.4 grams higher than on basis of mineral fertilizers (Background), and under the influence of Rival stimulator-3.0-6.0 grams [20]. According to Khayrullaev S. S, In the variant, where not used mineral fertilizers and micronutrients, the

leaf area in the control variant of the Orzu variety of soybean was 51.1 thousand m^2 / ha. Under the influence of microelements, the leaf area of Orzu was 59.1-64.6 thousand m^2 / ha. The highest rates of exposure to micronutrients were observed with medium use of sulfur and manganese. Under influence macro and micro fertilizers, the leaf area of Orzu variety increased from 4.0 to 13.5 thousand m^2 / ha, or from 7.3 to 20.9% [21].
It was found that when the plants were exposed to urea at different rates, they had an effect on their biometric indicators, and when the urea rate was increased to 15 grams, all biometric indicators were better than other options (Umarova Nigora Sadriddinovna, et.al. 2023) [22]. The application of stimulants to plants increases their resistance to abiotic factors. All the stimulators in the experiment showed their effect for the preservation of the plant, and the foliar feeding variant of the fulvogummat stimulator showed a better result than the other stimulators (Usmonova Shokhista Usman kizi, et.al. 2023) [23].
Usmonova Shokhista and other scientists noticed that the growth process has a great role in the formation of the plant's fruit, and the use of stimulants in the experiment showed a positive effect on the growth process of the plant. The studied stimulators have an effect on the growth process, among the stimulators Fulvogummat stimulator was 164.9 cm tall when fed from the leaf, and recorded a good indicator among the variants (Usmonova Shokhista Usman kizi and et.al. 2023) [24].

2. Materials and Methods

Research work was carried out in field and laboratory conditions. Placement of field experiments, observation, and calculations "Methods of carrying out field experiments", soil and plant analysis "Methods of agrochemical, agrophysical and microbiological research in irrigated cotton areas", "Methods for studying biological fixation of air nitrogen", methodological manuals, biochemical analysis of soybeans is carried out using the Granoluser apparatus increased.
In scientific sources, it is noted that 150-250 kg of biological nitrogen accumulates in 1 hectare of soybean crop during the season with the participation of bradyrhizobium japonicum. However, taking into account the fact that in the conditions of Uzbekistan, the amount of nitrogen absorbed by the bacteria from the air accumulates in plant growth organs and generative organs, the amount of nitrogen, phosphorus, potassium released by the crop and the amount of nitrogen remaining in the soil, we studied the absorption of air nitrogen in different varieties and inoculants.
We determined the assimilation of air nitrogen with the presence of bradyrhizobium japonicum in the soybean crop according to the methodology of S.A. Posypanov (1990.-B.27-40). In this method, by planting inoculated and non-inoculated seeds, the amount of nitrogen in the vegetative and generative organs of the plant is compared, and the amount of nitrogen accumulated by nodule bacteria is determined based on the difference between them. This method is not recommended for use on other legumes than soybeans, as aboriginal nodule bacteria from other legumes may be present in the soil. Due to the fact that soybeans have not been planted in Uzbekistan for many years, there are no aboriginal strains of pathogenic bacteria in the soils of the republic. The absence of soybean aboriginal nodule bacteria in the soils we conducted the experiment was determined before the experiment. The amount of nitrogen, phosphorus, and potassium in soybean roots, stems, leaves, and root nodules was determined during the podification phase. (Methods of chemical analysis of plants V.L.Mukhanova 1977) This method was developed taking into account the fact that it can be used in field experiments, that inoculated and uninoculated plants absorb mineral nitrogen in the soil in the same amount in many experiments (S.A. Posypanov, 1990. -B. 27-40).

The Experimental Scheme

Varieties	Rate of fertilizers, inoculants
Orzu	1. Control - background ($N_{22}P_{92}K_{60}$), no inoculant applied
	2. Background - $N_{22}P_{92}K_{60}$+*Bradyrhizobium japonicum Bacillus subtilis* BS-26, 2.0 l/ha titer 22 billion/ml
	3. Background - N_{22} $P_{92}K_{60}$+Ligabact pronok 2.0 l/ha titer 20 billion/ml
ES-Mentor	1. Control - background ($N_{22}P_{92}K_{60}$), no inoculant applied
	2. Background - $N_{22}P_{92}K_{60}$+ *Bradyrhizobium japonicum Bacillus subtilis* BS-26, 2.0 l/ha titer 22 billion/ml
	3. Background - $N_{22}P_{92}K_{60}$+Ligabact pronok, 2.0 l/ha titer 20 billion/ml

we compared the effectiveness of domestically produced and imported strains of inoculants in soybean cultivation. From mineral fertilizers, nitrogen 22 kg/ha, phosphorus 92 kg/ha, potassium 60 kg/ha were used as

background in the experiment. Ammophos (N-11%, P-46%), potassium chloride (K-60%) was applied before plowing the land.
Field experiments were conducted on the basis of the adopted technological map of soybean cultivation for the region, excluding the variants studied in soybean cultivation.

3. Results and Discussion

The role of mineral fertilizers and inoculants in the symbiotic activity of soybean varieties
The number of nodules formed in the root of the plant was studied in the phases of leaf emergence, flowering and podding. It was found that when Ligabact pronoc was used in the Es-mentor variety at the beginning of true leaf development 9.2 pieces of buds were formed, in the flowering phase, it was 32.4 pieces, in the period of pod formation, 202.6 pieces were formed. In Orzu variety, 6.4 pieces of true leaves were produced, 28.2 pieces of pods were formed during flowering, and 176.4 pieces of pods were formed in pod formation. *Bradyrhizobium japonicum Bacillus subtilis* BS-26, the number of nodules in the variants used was 5.2 pieces at true leaf release, 24.4 pieces at flowering, 168.2 pieces at podding in Es-mentor variety and 4.8 pieces at at true leaf release, 20.2 at flowering, and 158.6 pieces at podding in Orzu variety. It was observed that no buds were formed in both varieties in the variants without inoculant and fertilizer.

The content of nitrogen, phosphorus and potassium in the vegetative organs of soybean varieties under the influence of mineral fertilizers and inoculants
When the amount of nitrogen, phosphorus, and potassium in the plant vegetative organs and nodules formed in the root was determined in the phase of podding, the amount of nitrogen in the root was 4.86% in the Es-Mentor variety compared to the control in the variant where the Background+Ligabact pronok 2.0 l/ha titer of 20 billion/ml was used 4.86% and 4.72% in Orzu variety, these indicators were found to be 2.43 and 2.56% more than the control. Such results were also observed in the variant using Background + *Bradyrhizobium japonicum +Bacillus subtilis BS-26, but the indicators* were lower compared to the Background + Ligabact pronok 2.0 l/ha titer of 20 billion/ml, and 2.08; 2.15% more was noted compared to the control according to the varieties.

Table 1. Amount of NPK in the soybean plant during the podding phase, % (in dry mass), 2021-2023

Options	**Es-Mentor**			**Orzu**		
Root						
	N	P	K	N	P	K
Control - background ($N_{22}P_{90}K_{60}$)	2,43	0,84	2,56	2,26	1,24	2,65
Background+ Ligabact pronok 2,0 l/ha titer 20 billion/ml	4,86	1,68	2,20	4,72	1,07	2,28
Background+ *Bradyrhizobium japonicum* +Bacillus subtilis BS-26	4,38	1,26	2,43	4,34	0,84	2,56
Stem						
Control - background ($N_{22}P_{90}K_{60}$)	2,24	2,36	8,3	2,23	1,24	6,96
Background+ Ligabact pronok 2,0 l/ha titer 20 billion/ml	3,32	2,28	6,8	3,2	1,20	5,98-
Background+ *Bradyrhizobium japonicum* +Bacillus subtilis BS-26	2,92	2,32	7,3	2,88	2,22	6,00
Leaf						
Control - background ($N_{22}P_{90}K_{60}$)	4,6	2,55	3,42	3,51	2,90	2,36
Background+ Ligabact pronok 2,0 l/ha titer 20 billion/ml	6,8	1,76	3,34	5,46	2,50	2,20
Background+ *Bradyrhizobium japonicum* +Bacillus subtilis BS-26	6,1	2,38	3,36	4,82	2,65	2,31
Nodule						
Control - background ($N_{22}P_{90}K_{60}$)	-	-	-	-	-	-
Background+ Ligabact pronok 2,0 l/ha titer 20 billion/ml	27,1	3,76	8,86	20,2	3,48	7,15
Background+ *Bradyrhizobium japonicum* +Bacillus subtilis BS-26	18,2	3,96	10,74	15,8	3,69	7,42

The analysis shows that the application of inoculants significantly increased the nitrogen content of the roots compared to the control. The amount of phosphorus and potassium showed a tendency to decrease in the variants with inoculants compared to the control, and depending on the variants, the phosphorus content was from 0.84 to 1.68% in the Es-Mentor variety, from 1.24 to 0.84% in the Orzu variety (Table 1).
Depending on the options, the amount of potassium was also 2,56-2,20% in Es-Mentor variety; and 2.65-2.28% in Orzu variety. In the control variant, the amount of potassium was higher than in the variants treated with inoculants.
The analysis showed that the amount of nitrogen in the soybean stem was lower than in the root, and the amount of phosphorus and potassium was higher. It was found that the amount of nitrogen in the leaf is higher than in the stem and root in both varieties. But it was observed that the amount of phosphorus is closer to the values of the stem, and the amount of potassium was less than stem.
It was found that the content of nitrogen, phosphorus and potassium in the nodules formed in the root was significantly higher than in the content of the root, stem, and leaf. Compared to the control variety, the amount of phosphorus and potassium was lower in the options using inoculants, especially in the Es-Mentor variety Orzu variety and Background+ Ligabact pronok 2.0 l/ha titer 20 billion/ml, the amount of phosphorus and potassium in the option using Background+ *Bradyrhizobium japonicum* +Bacillus subtilis BS-26 was used the pattern of decrease was observed in the variant. The results of the analysis showed that this was definitely caused by the large amount of biomass and grain yield.

The effect of mineral fertilizers and inoculants on the yield structure indicators of soybean varieties
The effect of inoculants on the parameters of the yield structure of soybean varieties, i.e. the height of the plant, the number of pods per plant, the number of grains per pod, the mass of grains per plant and the mass of 1000 grains were analyzed (Table 2).

Table 2. The effect of different inoculants on the yield structure of soybean varieties, (2021-2022)

No	Variants	Plant height, cm	On a single plant number of pods, pcs	The number of grains in one pod, pcs	On a plant number of grains, pcs	On a plant mass of grains, g	Mass of 1000 grains, g
Es-Mentor							
1	Control - background ($N_{22}P_{90}K_{60}$) (inoculant not used)	85,5	21,6	2,2	47,5	8,3	174,2
2	Background+ *Bradyrhizobium japonicum* + *Bacillus subtilis* BS-26	93,3	26,2	2,6	68,1	12,3	180,2
3	Background+Ligabact pronok	97,7	30,1	2,8	84,2	15,7	186,2
Orzu							
1	Control - background ($N_{22}P_{90}K_{60}$) (inoculant not used)	83,7	20,2	2,0	40,4	5,2	129,4
2	*Background+Bradyrhizobium japonicum* +Bacillus subtilis BS-26	91,5	23,4	2,8	65,5	8,8	134,6
3	Background+Ligabact pronok	93,6	26,7	3,0	80,1	11,1	138,2

In our experiment, the height of the plant in the Es-mentor variety changed from 85.5 to 97.7 cm, and in the Orzu variety from 83.7 to 93.6 cm under the influence of the applied inoculants. The height of soybean varieties, the number of pods per plant, the number of grains per pod, the number and weight of grains per bush, and the mass of 1000 grains were observed under the influence of inoculant strains. These values were higher in both

cultivars when Ligabact pronoc+$N_{22}P_{92}$ K_{60} kg/ha was applied compared to *Bradyrhizobium japonicum* + *Bacillus subtilis* BS-26 + $N_{22}P_{92}K_{60}$ kg/ha.
It was observed that the mass of grains per plant was also increased in both cultivars compared to the control variant. The weight of 1000 grains varied from 174.2 to 186.2 g in the Es-mentor variety, from 129.4 to 138.2 g in the Orzu variety, and the 1000 grain weight of the Es-mentor variety was higher in all studied variants.

Effects of mineral fertilizers and inoculants on yield of soybean varieties
Depending on the options, the yield of the Es-mentor variety varied from 16.9 to 25.5 c/h, and from 14.1 to 21.7 c/h in Orzu variety.

Table 3 The effect of inoculants on the yield of soybean varieties, (2021-2022)

No	Options	Yield, c/ha			Additional yield	
		2021	2022	Average	c/ha	%
Es-Mentor variety						
1	Control - background ($N_{22}P_{90}K_{60}$) (inoculants not used)	17,4	16,4	16,9	-	-
2	Background+ *Bradyrhizobium japonicum* + *Bacillus subtilis* BS-26	24,2	22,1	23,1	6,5	38,0
3	Background+Ligabact pronok	26,4	24,6	25,5	8,6	50,9
Orzu variety						
1	Control - background ($N_{22}P_{90}K_{60}$) inoculant not applied)	16,0	12,2	14,1	-	-
2	*Bradyrhizobium japonicum* +Bacillus subtilis BS-26	22,4	16,6	19,5	5,4	38,3
3	Background+Ligabact pronok	24,6	18,8	21,7	7,6	54,0

As a result of the use of inoculant strains, the additional yield in the Es-mentor variety was 6.5 and 8.6 c/ha, and in the Orzu variety it was 5.4 and 7.6 c/ha. The effectiveness of inoculants was found to be the highest when Ligabact pronok + $N_{22}P_{92}K_{60}$ kg/ha was used (table 3) .

4. Conclusions

1. In the conditions of irrigated typical gray sierozem soils of the Tashkent region, the inoculants include *Bradyrhizobium japonicum Bacillus subtilis* BS-26 created in our republic and 3 Ligabact pronoc *Bradyrhizobium japonicum* (109), *Bradyrhizobium diazoefficiens* (USDA110), *Bradyrhizobium elkanii* (E123)+ brought from the Russian Federation. When nodulating bacteria with 0.5% molybdenum were used on soybeans planted in the stabble, the growth and development of plants, the dynamics of the formation of nodules in the roots, the changes in the amount of nitrogen, phosphorus, potassium accumulated in the nodules formed in the roots, stems, leaves, roots depending on the varieties, applied inoculants, it was found to have a significant effect on yield and yield structure.
2. It was found that the amount of nitrogen, phosphorus and potassium in the nodules formed in the root is significantly higher compared to the content of the root, stem, and leaf. Compared to the control variety, the amount of phosphorus and potassium was lower in the options using inoculants, especially in the Es-Mentor variety Orzu variety and Background+ Ligabact pronok 2.0 l/ha titer 20 billion/ml, the amount of phosphorus and potassium in the option using Background+ *Bradyrhizobium japonicum*+Bacillus subtilis BS-26 was used the pattern of decrease was observed in the variant. The use of inoculants had a positive effect on increasing the amount of nitrogen in the roots, stems, leaves and nodules.
3. In Es-mentor variety, depending on options, it changed from 16.9 to 25.5 c/ha, in Orzu variety from 14.1 to 21.7 c/ha. As a result of the use of inoculant strains, the additional yield in the Es-mentor variety was 6.5 and 8.6 c/ha, and in the Orzu variety, it was 5.4 and 7.6 c/ha. The effectiveness of inoculants was found to be the highest when Ligabact pronok+ $N_{22}P_{92}K_{60}$ kg/ha was used.

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