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ORIGINAL ARTICLE

Symbiotic potential of snap beans (*Phaseolus vulgaris* L.) depending on biological products in agrocoenosis of the Right-Bank Forest-steppe of Ukraine

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The topicality of the research is determined to the search for new approaches to the development of technological techniques for growing beans, taking into account the soil-climatic conditions of the Right-Bank Forest-steppe of Ukraine. The research on the dynamics of the formation and the symbiotic apparatus functioning has been carried out; the influence of the nodule bacterium's new strains on the activity of the symbiotic apparatus formation in the snap bean agrocenosis (*Phaseolus vulgaris* L.) has been investigated. It is proved that the use of biopreparations provides an increase in interphase periods. At the same time, the influence of the complex application of inoculation with bacterial preparations of Azotophyte-l, Biomag, Biocomplex-BTU-l on the basic symbiotic productivity indexes of snap bean crops, in particular the number and weight of active bulbils, the active symbiotic potential and yield of beans long pod of sorts of early ripeness group were studied. It was established that the use of the bacterial preparation of Biocomplex-BTU-l contributes to the increase of the number and the mass of bulb formations on the root system of the Zironka sort. The usage of a bacterial preparation Biocomplex-BTU-l contributes to receiving 18.4 t/ha or 9.4 t/ha of crop rise, and the correlation between yield and studied indexes were determined. The usage of Azotophyte-l and Biomag for pre-crop preparations of bean seeds is ineffective.
Keywords: Snap beans; agrocenosis; tuberous bacteria; symbiotic productivity; yield

Introduction

The history of discovering the tuberous bacteria is closely connected with studying legumes used by people. The first mentions about growing legumes date from 4-5 millennia BC (Parmar et al., 1999, Figueiredo et al., 2007, Rajendran et al., 2012). Symbiosis with tuberous bacteria is one of the most effective systems of biological nitrogen fixation, which is of great ecological significance. In the bean-nodule symbiosis, a combination of two biochemical processes-nitrogen fixation and photosynthesis is received, with a help of which the nitrogen-carbohydrate balance of the plant organism stabilizes (Albinus, 2008; Beneduzi, 2012; Figueiredo et al., 2010). Microorganisms introduced into the root zone are capable to form active vegetative-bacterial associations, activate the processes of nitrogen fixation and photosynthesis, stimulate the development of the root system, increase the absorption capacity of the root system, which in general has a positive effect on the degree of plant absorption of nutrients from the soil (Patika, 1999; Chen, 1994). That's why the study of biological and biochemical features of the fixation of molecular nitrogen process by microorganisms gets a paramount importance.

The most practical significance in the enrichment of the soils with nitrogen, due to its absorption from the air, has groups of soil microorganisms-tuberous bacteria which fix molecular nitrogen in symbiosis with leguminous plants. The representatives of the family of tuberous bacteria, namely Bradyrhizobium, Rhizobium Mezorhizobium, Sinorhizobium, Azorhizobium and Allorhizobium, are soil microorganisms which, in addition to free-living heterotrophic organisms, have a stage of symbiotic reciprocity with legumes plants (Martyniuk et al., 2012; Mohamed et al., 2009). The important role in the relationships of micro-and macrosymbiote is devoted to the genetic nature of the strain and the plant sort. The stresses plants and bacteria fall under (low and high temperatures, lack of moisture or overwatering, low acidity of the soil) can negatively affect bean nodule symbiosis (Antipchuk, 1994; Margeson, et al., 1980). Optimal conditions for effective action of bacterial fertilizers are: 20-25 °C, pH 6.5-7.5, 60-70% of total moisture content (Volkogon, 2011; Kloepper et al., 1980).

Bean vegetable is considered as one of the most important legumes in the world agriculture, which accumulates biological nitrogen with a help of symbiosis with tuberous bacteria. Along with the traditional bean sorts, it is a valuable high-protein plant whih is used for human nutrition. The high level of protein and minerals makes it essential in overcoming the problem of plant protein in Ukraine and the world (Scheer, 2004; Tahmasebpour et al., 2013; Watson et al., 2012).

In agricultural production, the positive role of legumes depends on the life of tuberous bacteria with which these plants are in

close symbiotic relationships. It can be considered that their productivity, the yield, the accumulation of biological nitrogen and vegetable proteins to a greater extent depend on the nature of the relationship between these two organisms formed in each individual case. In the event of the active complex "legume plant-nodule bacteria", which is useful for both organisms for coexistence-a symbiosis is formed in the process of which the energy of the sun is used to bind the biological nature of atmospheric nitrogen (Kots, 2007; Jangu et al., 2011; Kalra, 1995).
One of the new environmental trends in modern agricultural science is the development of measures which increase the biological fixation of nitrogen and the mobilization of phosphorus and potassium on dropping legumes, which is essential for increasing the yields, for the decrease of the prime cost of agricultural products and energy consumption for its production, and environmentalizing the agriculture. In developed countries, the interest to the problem of biological nitrogen has increased significantly because of that. Currently, there are two main ways of increasing nitrogen fixation in agro-ecosystems. The first is the activation of the natural population of nitrogen-fixing microorganisms activity in the rhizosphere and on the roots, and the second is the inoculation of legumes seeds with high-activy strains of nitrogen-fixating and phosphate-mobilizing microorganisms (Derevyansky, 2012; Petrichenko, 2012; Gamalero et al., 2011). The inoculation of seeds before sowing with active strains of nitrogen fixators is effective to increase the symbiotic and associative nitrogen fixation in ecosystems, which significantly compensates lack of nitrogen and increases plant productivity (Volkogon, 2008). Microorganisms associated with plants are considered as the factors of stimulating growth and development of plant (Schwartz, 2013; Derevyansky, 2012; Li et al., 2008). Taking to account the literary sources, it has been established that the biological method of growing leguminous plants, in the results of the usage of which the clean environment, environmentally safe high-quality products are received, the natural fertility of soils reproduces in the agricultural production, and it should become one of the main ways to improve agricultural production (Hamaoui et al., 2001; Osoro et al., 2014; Hung et al., 2004).
Nitrogen fixing potential of legumes symbiosis with nodule bacteria in the soil is often limited with a low nitrogen-fixing activity of bacteria or a lack of their number in the zone of coming up seeds (Gupta et al., 2000; Hosseinpur et al., 2012). Due to this, an obligatory element of the growing legumes technology is the pre-sowing treatment of seeds with biopreparations based on selective strains of nodule bacteria, which do not only increase the productivity of plants, but also further the introduction of highly effective tuberous bacteria strains into the soil microbiocenosis (Budwina, 1997; Duparque, 1996).

Materials and methods of research

Researches on the study of the symbiotic potential of snap beans, depending on the biological preparations in vegetable agrocenosis, were conducted in 2016-2017 on the experimental field of the Vinnytsia National Agrarian University. Gray forest soli, medium loam soil, are characterized with the following indicators: humus content-medium (2.4%), P_2O_5 (271.2 mg/kg) and K_2O (220.0 mg/kg) content is very high. Acidity of the soil is close to neutral. Field experiments were laid out with randomized blocks, a four-time repetition. During the research, the experimental scheme was developed in accordance with the existing methodology in the experimental case, and general observations, records, calculations with the snap beans Zironka sort were carried out.
The following preparations of biological origin were used in the experiment: Azotophyte-l, Biomag, Biocomplex-BTU-l The control variant was one in pre-sowing of which the seed cultivation was not used. During the experimental work field, statistical and laboratory methods of research were used, where the beginning and large appearance of button, the phase of budding, mass flowering, the beginning of technical ripeness and the end of the growing season were marked. During the growing season snap beans the number and weight of the tuberous bacteria were determined; the fruits were collected selectively, as they formed in accordance to the requirements of the current standard "DSTU 4794: 2007 Beans. The growing technology. General requirements (Gosstandart of Ukraine, 2009). The weight of the fruits from each area was determined separately with the weighing method. The results of snap bean yields indexes received in the researches were treated with the method of dispersion analysis (Bondarenko et al., 2001).

Results and discussion

The analysis of the number of bulbils and the weight of snap bean showed that the seed inoculation of Zironka sort promoted to increasing the total number of tuberous on the root system of the plant (Table 1).
In the phase of mass flowering, the largest number of tuberous was formed in the variant with the usage of biopreparations Biocomplex-BTU-l-28.5 pc/plant, which was in 9.3 pc more than the control version. Biopreparations of Azotophyte-l contributed to the formation of tuberous in the amount of-23.6 pc/plant, which exceeded the variant without pre-sowing seed treatment at 4.4 pt/plant. The smallest increase, in comparison to control, among the used biopreparations was provided with Biomag, was 21.1 pc/plant, but in 2.5 pc per plant was less than the one used for Azotophyte-l and in 7.4 pc/plant less in comparison to the usage of Biocomplex-BTU-l.
The usage of biopreparations also affected on the mass of tuberous. It was the biggest in the variant with application of biopreparations Biocomplex-BTU-l-0.62 g/plant. The usage of Azotophyte-l or Biomag contributed to receiving a smaller mass of tuberous in comparison to the variant with using Biocomplex-BTU-l, but the indicators were higher in comparison to the control variant. Thus, the application of Azotophyte-l and Biomag contributed to the formation of tuberous mass at the levels of 0.35 and 0.48 g/plant, which exceeded control variant in accordance in 0.12 and 0.25 g/plant.

Table 1. Effectiveness of symbiotic productivity of snap bean (*Phaseolus vulgaris* L.) depending on biopreparations, Zironka sort (average for 2016-2017 year).

Variant	The number of bulbils, pc./plant	Mass of bulbils, gram/plant
	Phase of mass bloom	
Without pre-sowing cultivation (C*)	19.2	0.23
Azotophyte-l	23.6	0.48
Biomag	21.1	0.35
Biocomplex-BTU-l	28.5	0.62

Note: C*-control

The general symbiotic potential of snap beans in the Zironka sort determined its dependence on the biopreparations and bacteria which are the part of their basis (Table 2).

Table 2. The general symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biopreparations of Zironka sort (average for 2016-2017 y.), thousand kilo day/ha.

Variant	Interphase periods of plants, thousand kilo day/ha			
	Mass appearance of budding	Mass appearance-mass flowering	Mass appearance-the beginning of technical ripeness	Mass appearance-the end of growing period
Without pre-sowing cultivation (C*)	1.2	2.5	13.4	19
Azotophyte-l	1.5	3.1	15.3	21.1
Biomag	1.3	2.7	14.9	20.4
Biocomplex-BTU-l	1.8	4.2	18.7	26.3

Note: C*-control

It is noted that the maximum index of the total symbiotic potential of beans is formed during the period of vegetation "mass appearance-budding" with the usage of biopreparations Biocomplex-BTU-l-1.8 thousand kg, days/ha in the variant without the usage of biopreparations, the magnitude of the total symbiotic potential was 1.2 thousand kg, days/ha, which was less than the mentioned variant in 0.6 thousand kg. days/ha. At the same time, it was noted that the usage of Azotophyte-l or Biomag contributed to the increase in the formation of the general symbiotic potential, where the index was 1.5 and 1.3 thousand kg, days/ha.

With the onset of the next interphase periods, the general symbiotic potential during the vegetative period of the snap bean grew. The regularity between the studied variants in all interphase periods did not changed. Thus, the greatest potential was received with the usage of biopreparations Biocomplex-BTU-l, in particular in the interphase period, "mass appearance - the end of vegetation", where the shown period was the highest and was 26.3 thousand kg day/ha, which exceeded the control variant in 7.3 thousand kg day/ha. The smallest increase in comparison to the variant, where the biopreparations were used, was with the usage of biopreparations Biomag-20.4 thousand kg, days/ha.

It was established that the magnitude of the active symbiotic potential increased gradually during the growing vegetative mass and vegetation period of snap beans (Figure 1). Thus, during the period of "mass appearance - budding" the active symbiotic potential varied depending on the studied variant. Application of biopreparations Biocomplex-BTU-l contributed to the formation of active symbiotic potential at the level of 6,7 thousand kg. days/ha, which is in 6,1 thousand kg. days/ha more than the control variant. The usage of Azotophyte-l or Biomag biopreparations also contributed to an increase of the active symbiotic potential of the plant. In the interphase period "mass appearance-mass flowering" the index was at the level of 0.7-2.0 thousand kg, days/ha. In the next interphase periods, the increase of the researched indicator was observed.

In the interphase periods, "mass apearance-the beginning of technical ripeness" and "mass appearance-the end of the vegetation," the indicators varied in the following limits: with the usage of biopreparation Azotophyte-l it was 7.9-12.4 thousand kg. days/ha, and with Biomag-6.6-9.7 thousand kg, days/ha. It was established that the most propitious conditions for the formation of the maximum magnitude of the active symbiotic potential were noted in the variant with using Biocomplex-BTU-l-10.5-16.8 thousand kg, days/ha, which exceeded the variant where the pre-sowing seed preparation was not used.

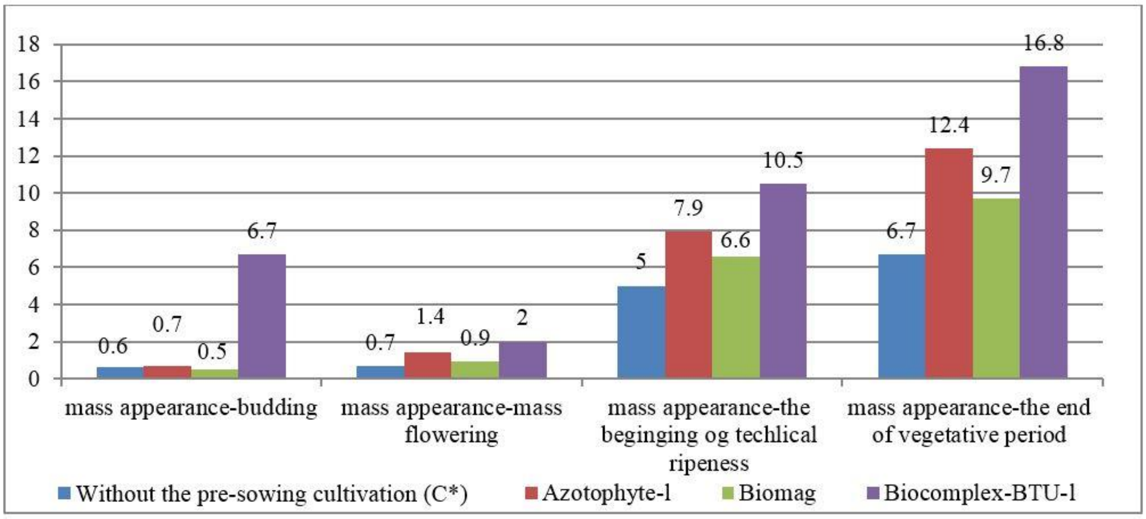

Figure 1. Dynamics of the active symbiotic potential of snap bean (*Phaseolus vulgaris* L.) depending on the biopreparations in the Zironka sort (average for 2016-2017), ths, Kg, days/ha. C*-control.

On average, during the years of the research the significant impact of biopreparations on the yield of snap beans has been established. The maximum magnitude was received from the variant where the Biocomplex-BTU-l was used (Table 3).

Table 3. The yield of snap bean (*Phaseolus vulgaris* L.) of Zironka sort depending on the usage of biopreparations, tons/hectare.

Variant	The yield, tons/hectare %			± before the control, tons/hectare %
	2016 y.	2017 y.	average	
Without pre-sowing cultivation (C*)	12.9	19.2	16.1	-
Azotophyt-l	16.7	25.3	21	4.9
Biomag	19.1	23	21.1	5
Biocomplex-BTU-l	25.5	32.7	29.1	13
NIR_{05}	0.98	0.83	-	-

Note: C*-control.

At the same time, the yield was 29.1 t/ha and exceeded the control version in 13.0 t/ha. Also at the same time, the mathematical analysis has determined that the applied biopreparations affect both the yield of snap beans, the mass of tuberous and the biometric indixes of the plant. As a result of the usage of Azotophyte-l, the yield of beans is closely related to the mass of tuberous, where the correlation coefficient was r=0.99 and the total number of beans per plant and their length. The application of Biomag and Biocomplex-BTU-l also determined the close dependence of yields on the total number of beans and their length, but the magnitude of the correlation was somewhat lower and was r=0.61-0.67.
As a result of the application of Azotophyte-l, which is based on the nitrogen-fixing bacteria Azotobacter chroococcum and because of their active activity, contributed to the fact that the total number of beans, their length is closely related to the mass of the tuberous with the magnitude of the correlation coefficient r=-0.99 and r=-0.82 respectively. Because of the usage of Biomag or Biocomplex-BTU-l, the dependence of the number of beans on the mass of tuberous was also quite high and was r=0.69 and r=0.94.

Conclusions

On the base of carried out researches, the following conclusions can be drawn 1. The amount of accumulation of biological nitrogen is directly influenced with soil-climatic conditions and applied biopreparations 2. The maximum realization of the symbiotic potential of snap bean plants of Zironka sort is created with the usage of Biocomplex-BTU-l at a dose of 0.5 l/ha, 3. Treating snap beans seeds with Azotophyte-l with a dose of 0.5 liters per hectare or Biomag is ineffective.

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