Economic efficiency of bacterial fertilizers application on soybean in the Oryol region

A G Vasilchikov1*, A S Semenov1 and V I Zotikov1

1Federal State Budgetary Scientific Institution “Federal Scientific Center of Legumes and Groat Crops”, p/b Streletskoye, Orel, 302502, Russia

E-mail: office@vniizbk.orel.ru

Abstract. The research was conducted at FSCLGC in 2015-2019. The responsiveness of new varieties to inoculation with a set of active nodule bacteria strains 634, 626, 640, 645, 650 was studied in comparison with the standard Lanceolate variety on dark gray forest medium loamy soil. The scheme of the experiment included options without inoculation and fertilization (control), with inoculation with the specified strains, as well as with the introduction of mineral nitrogen at a dose of 60 kg of a.s./ha. The experience is replicated four times. The area of plots is 10 m². Sowing was carried out with a SKS-6-10 seeder in a wide-row method (row spacing 45 cm) in the second decade of May. The seeding rate is 600 thousand germinating seeds. Both inoculation of seeds and application of mineral nitrogen at a dose of 60 kg per hectare caused an increase in soybean yield. Crop increases, depending on the year and variant, were 0.6-2.7 C/ha. The highest yield – 28.2 C/ha (on average for 2 years) formed the Leader-10 variety. The analysis of the economic efficiency of cultivation of various soybean varieties showed that the profitability of cultivation of the Leader-10 variety, which is characterized by a higher level of productivity, is significantly higher than other evaluated varieties. According to the strain factor, soybean cultivation using inoculants based on highly active nodule bacteria strains complementary to each variety is more cost-effective than using mineral nitrogen fertilizers.

1. Introduction

Soybean is one of the main crops of modern world agriculture. The nutritional value of soybean is determined by the presence of almost all the elements of nutrition necessary for living organisms [1]. In terms of production, it ranks fourth in world agriculture after wheat, corn and rice.

In recent years, global soybean production has fluctuated around 340-350 million tons [2]. In Russia, the acreage occupied by soybeans remains positive. The average annual increase in the area of soybean crops in Russia over the past 10 years was 13.4%, which made it possible to collect 4.36 million tons of seeds in 2019. At the same time, the main growth in acreage is due to an increase in crops in the Central region of Russia (Kursk, Belgorod, Orel) [3]. In 2019, 119 thousand hectares of soybeans were harvested in the Oryol region and 195 thousand tons of seeds were collected with a yield of 16.7 C/ha. In the Oryol region, according to climatic conditions, it is possible to cultivate only precocious varieties. At the same time, the observed trend of climate change towards warming may contribute to the cultivation of varieties with a longer growing season. Recently, for cultivation in the Oryol region, in addition to traditional varieties, such as Lancet, Swapa, Zusha, Osmon and others, such varieties as Leader-1 and Leader-10, declared by LLC AST, are of great interest. In terms of maturation time, Leader-1 belongs to the early-to-medium category and Leader-10 belongs to the average maturation period category.
The value of soybean, in addition to food and feed advantages, is determined by the fact that it is a highly effective plant-microbial system that performs the process of biological nitrogen fixation. Inoculation of plants with highly effective strains of nodule bacteria increases the productivity of legumes by an average of 10-25% [4].

When symbiotic nitrogen is actively bound, soybeans can absorb up to 200 kg/ha of nitrogen from the air, satisfying 60-70% of their needs and replenishing soil nitrogen reserves by leaving plant residues [5,6,7]. An effective way to increase soybean productivity is to search for new more active strains of nodule bacteria and bacterize seeds with drugs made on the basis of these strains. The presence of such a phenomenon as variety-strain specificity makes it possible to select the strains that most effectively interact with certain soybean varieties [8].

In this regard, the identification of varieties that are most suitable for the soil and climatic conditions of a particular region, the development of energy and cost-effective methods for increasing productivity based on optimizing the conditions of symbiotic and photosynthetic activity of crops due to inoculation of seeds with an active strain of nodule bacteria is an urgent task.

2. Materials and methods

The research was carried out in 2015-2019 in the field at the experimental site of the laboratory of genetics and biotechnology of FSCLGC using the field experience method [9]. In three series of experiments responsiveness to nitrogenization of promising lines of soybean was evaluated. As a control, the soybean variety Lanceolate was used. For each variety, the following options were laid: control without inoculation, a variant with the introduction of mineral nitrogen at a dose of 60 kg of active substance per hectare, and variants with inoculation with strains 634, 645 and 650. The soil of the experimental site is dark gray forest heavy loam with an arable layer of 28 cm thick. The average temperature, in addition to food and feed advantages, is determined by the fact that it is a highly effective plant-microbial system that performs the process of biological nitrogen fixation. Inoculation of plants with highly effective strains of nodule bacteria increases the productivity of legumes by an average of 10-25% [4].

Average annual temperature, in addition to food and feed advantages, is determined by the fact that it is a highly effective plant-microbial system that performs the process of biological nitrogen fixation. Inoculation of plants with highly effective strains of nodule bacteria increases the productivity of legumes by an average of 10-25% [4].

| Table 1. Meteorological conditions in 2015-2017. |
|-----------------------------------------------|
| Indicators | year | May | June | July | August | September |
|------------|------|-----|------|------|--------|-----------|
| Average annual precipitation                  | 53   | 61  | 80   | 67   | 57     |
| Average annual temperature, t\(^o\)            | 13.0 | 16.9| 18.5 | 17.1 | 11.7   |
| Precipitation mm                                | 2015 | 64.7| 38.3 | 68.5 | 8.2    | 68.7      |
| mm                                                | 2016 | 63.2| 68.4 | 127.6| 105.9  | 20.7      |
| 2017                                              | 54.0 | 59.8| 142.2| 87.2 | 16.0   |
| 2018                                              | 31.9 | 16.1| 109.0| 16.5 | 41.5   |
| 2019                                              | 105.9 | 37.6| 85.9 | 37.8 | 43.9   |
| Average temperature, t\(^o\)                    | 2015 | 15.1| 18.4 | 19.2 | 18.7   | 15.6      |
| 2016                                              | 14.2 | 18.1| 20.9 | 19.9 | 11.9   |
Analyzing the weather conditions over the years of the experiments, we can say that the most favorable years for the development of soybeans were 2016 and 2018. 2017 and 2019 were characterized by low temperatures, and 2015 was characterized by a lack of moisture during critical periods for soybeans, which affected negatively the yield level.

Inoculation of promising soybean varieties and lines with three strains of nodule bacteria was evaluated during 2015-2017. According to the variety factor, the most productive for three years was the Leader-1 variety – 24.2 C/ha (table 2).

Table 2. Responsiveness of soybean varieties to inoculation (Aver. for 2015-2017 (C/ha)).

| Variants | Lanceolate | Osmon | L-216 | Leader-1 |
|----------|------------|-------|-------|----------|
| Control  | 22.1       | 22.4  | 20.0  | 22.8     |
| N60      | 24.2       | 24.1  | 22.1  | 24.5     |
| Strain 634 | 23.6   | 24.2  | 22.4  | 24.4     |
| Strain 626 | 24.4     | 23.9  | 21.5  | 24.9     |
| Strain 640 | 22.7     | 23.0  | 21.4  | 24.4     |
| Average by variety | 23.4 | 23.5 | 21.5 | 24.2 |

According to the strain factor, the highest yield was obtained on the Leader-1 variety with inoculation with strain 626 – 24.9 C/ha (table 3). The use of mineral nitrogen increased the cost of grain, while reducing the profitability: from 116% for line 216 to 140% for the Leader-1 variety. A high level of profitability (161-166%) was obtained with inoculation with all three strains, and the highest – 166% - with inoculation with strain 626 (table 3).

Table 3. Economic efficiency of using microbial drugs on soybean. (Aver. for 2015-2017 (C/ha)).

| Indicators | Lanceolate variety |
|-----------|-------------------|
|           | Contro  | N60  | Strain 634 | Strain 626 | Strain 640 |
| Yield, C/ha | 22.4 | 24.1 | 24.2 | 23.9 | 23.0 |
| Cost of gross output, rubles/ha | 49280 | 53020 | 53240 | 52580 | 50600 |
| Production costs, rubles/ha | 22100 | 22480 | 20600 | 20600 | 20600 |
| Cost price, rubles/C | 897 | 932.8 | 851.2 | 861.9 | 895.6 |
| Notional net income, rubles/ha | 29180 | 30540 | 32640 | 31980 | 30000 |
| Level of profitability, % | 145 | 136 | 158 | 155 | 146 |
| Actual economic effect, rubles/ha | 1360 | 3460 | 2800 | 820 |
| Osmon variety | 20.0 | 22.1 | 22.4 | 21.5 | 21.4 |
| Cost of gross output, rubles/ha | 44000 | 48620 | 49280 | 47300 | 47080 |
| Production costs, rubles/ha | 20100 | 22480 | 20600 | 20600 | 20600 |
| Cost price, rubles/C | 1005 | 1017 | 920 | 958 | 963 |
| Notional net income, rubles/ha | 23900 | 26140 | 28680 | 26700 | 26480 |
| Level of profitability, % | 119 | 116 | 139 | 130 | 128 |
| Actual economic effect, rubles/ha | 2240 | 4780 | 2800 | 2580 |
| Leader-1 variety | 216 Line | 20.0 | 22.1 | 22.4 | 21.5 | 21.4 |
| Cost of gross output, rubles/ha | 44000 | 48620 | 49280 | 47300 | 47080 |
| Production costs, rubles/ha | 20100 | 22480 | 20600 | 20600 | 20600 |
| Cost price, rubles/C | 1005 | 1017 | 920 | 958 | 963 |
| Notional net income, rubles/ha | 23900 | 26140 | 28680 | 26700 | 26480 |
| Level of profitability, % | 119 | 116 | 139 | 130 | 128 |
| Actual economic effect, rubles/ha | 2240 | 4780 | 2800 | 2580 |
According to the results of the experiments, in 2017, an experiment was laid, in the scheme of which, along with the most effective variety Leader-1, a promising variety of a later maturation period Leader-10 was included. The scheme of experiment included a comparison non inoculated control options with the introduction of mineral nitrogen dose of 60 kg/ha and inoculated with the production strain 634. In 2018, the scheme of this experiment versions were added with the inoculation of two promising strains 645 and 650, and is the class Leader-1 was added promising line L-85. The results of experiments for 2017-2018 and 2018-2019 are presented in tables 4,5.

Table 4. Economic efficiency of inoculation and mineral nitrogen application in soybean cultivation (average for 2017-2018).

| Indicator                      | Control | N60 | Strain 634 |
|--------------------------------|---------|-----|-------------|
| Lanceolate variety             |         |     |             |
| Yield, C/ha                    | 22.8    | 24.5| 24.4        |
| Cost of gross output, rubles/ha| 50160   | 53900| 53680       |
| Production costs, rubles/ha    | 20100   | 22480| 20600       |
| Cost price, rubles/C           | 882     | 916 | 844         |
| Notional net income, rubles/ha | 30060   | 31420| 33080       |
| Level of profitability, %      | 150     | 140 | 161         |
| Actual economic effect, rubles/ha| 1360   | 3020| 4120        |
| Leader-1 variety               |         |     |             |
| Yield, C/ha                    | 2.57    | 2.68| 2.70        |
| Cost of gross output, rubles/ha| 56540   | 58960| 59400       |
| Production costs, rubles/ha    | 20100   | 22480| 20600       |
| Cost price, rubles/ha          | 7820    | 8390| 7630        |
| Notional net income, rubles/ha | 36440   | 36480| 38800       |
| Level of profitability, %      | 181     | 162 | 188         |
| Leader-10 variety              |         |     |             |
| Yield, C/ha                    | 2.74    | 2.82| 2.89        |
| Cost of gross output, rubles/ha| 60280   | 62040| 63580       |
| Production costs, rubles/ha    | 20100   | 22480| 20600       |
| Cost price, rubles/ha          | 7340    | 7970| 7130        |
| Notional net income, rubles/ha | 40180   | 39560| 42980       |
| Level of profitability, %      | 200     | 176 | 209         |

Table 5. Economic efficiency of application of inoculants on soybean (average for 2018-2019).

| Indicator                      | Control | N60 | Strain 634 | Strain 645 | Strain 650 |
|--------------------------------|---------|-----|------------|------------|------------|
| Lanceolate variety             |         |     |            |            |            |
| Yield, C/ha                    | 22.1    | 24.0| 24.8       | 22.8       | 23.6       |
| Cost of gross output, rubles/ha| 48620   | 52800| 54560      | 50160      | 51920      |
| Production costs, rubles/ha    | 20100   | 22650| 20600      | 20600      | 20600      |
| Cost price, rubles/ha          | 909.5   | 943.8| 830.6      | 903.5      | 872.9      |
| Notional net income, rubles/ha | 28520   | 30150| 33960      | 29560      | 31320      |
| Level of profitability, %      | 142     | 133 | 165        | 143        | 152        |
With the current prices for soybeans (22-25 thousand rubles/ton), soybean is one of the highest-margin crops. Even with a yield of 1.5 t/ha, the profitability of its production is about 100% and at the same cost increases in proportion to the increase in yield.

An analysis of the economic efficiency of cultivating the varieties used in our experiment (table 4) shows that the profitability of cultivating the Leader 10 variety, which showed a higher yield, is significantly higher (195% and 158% on average for the variety, respectively) than the Lanceolate variety. The maximum level of profitability (209%) was obtained by inoculating the Leader 10 variety with strain 634.

4. Summary

According to the research results, experimental data were obtained showing that the cultivation of later-maturing and productive varieties that have time to ripe by the third decade of September can significantly increase the efficiency of soybean cultivation in the Oryol region. The highest level of profitability (209%) was obtained by inoculation with rhizotorphin based on strain 634 of the Leader-10 variety (average for 2017-18).

5. References

[1] Baranov V F, Kochegura A V, Lukomets V M 2009 Soybean in Kuban (Krasnodar: RSRIMK) 320
[2] Soybean harvest in 2019-20 MG is expected at last year level [Electronic resource]. URL: newsland. com/user/3759557959/content/urozhai-soi-v-2019-20-mg-ozhidaetsia-na-proshlogodnem-urovne/6916326 (access date 6.11.2019)
[3] Tikhonovich I A, Borisov A Yu, Vasilchikov A G 2012 Specificity of microbiological drugs for legumes and features of their production (Legumes and cereals) 3 11-17
[4] Mishustin E N, Shilnikova V K 1968 Biological fixation of atmospheric nitrogen (M: Science) 531
[5] Dorosinsky L M, Tilba V A, Begun S A 1976 Effect of bacterization on soybean yield and fixation of molecular nitrogen in the soils of the Far East Soybean and nitragin (NTB) 1 18-22
[6] Sinegovskaya V T, 2002 Optimization of the symbiotic and photosynthetic activity of soybean crops in the Amur region: author’s thesis for the degree of Doctor of Agricultural Sciences M 43
[7] Tilba V A, Shabaldas O G 2015 *Use of biological nitrogen as a means of biologization of the agricultural system* (Bulletin of the Stavropol AIC) **2** 96-100

[8] Polukhin A A, Panarina V I 2020 *Main problems of selection and seed production of agricultural crops and ways to solve them* (Zernobobovye i krupyanye kul'tury) **3(35)** 5-11

[9] Grudkina M, Polukhin A, Grudkina T 2019 *Factors increasing the effectiveness of state support in agriculture* (IOP Conference Series: Earth and Environmental Science) **274** 012113

[10] Hamitowa S M, Glinushkin A P, Avdeev Y M, Naliukhin A N, Kostin A E, Kozlov A V, Uromova I P, Rudakov V O, Tesalovskiy A A, Protopopova E V, Pigorev I Y, Polukhin A A, Sycheva I I 2017 *Condition Assessment Of Tree Plantations and Phytosanitary Properties of Soils in Cedar Groves* (International Journal of Pharmaceutical Research & Allied Sciences) **6(4)** 1-7

[11] Medvedev A V 2020 *Improving the innovative and entrepreneurial potential of irrigated agriculture in the South of Russia* (Russian Economic Bulletin) **3 (3)** 149-153

[12] Bayanova O V 2020 *Mechanism for ensuring the growth of feed crop production* (Russian Economic Bulletin) **3 (1)** 124-127