Efficient control of the productivity of agrophytocenosis of soybean (Glicyne max (L.) Merill)

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Abstract. Around the world, there is a surging demand for soy, the 'king of beans'. Soy is a globally traded foodstuff produced in both temperate and tropical regions and is a major source of protein and vegetable oils. In the conditions of the Kaliningrad region, the duration of soybean vegetation in soddy-weakly podzolic gleyic light loamy soil, with the medium reaction close to neutral, high and very high content of mobile phosphorus, and exchangeable potassium attains 144 days. The agrophytocenosis productivity is controlled through application of different mineral and bacterial fertilizers. Analysis of variance of the experimental data obtained in the study showed a pronounced relationship of 0.71 for the effect of the fertilizer system on quantitative indicators of the biological yield of soybean seeds. The effectiveness of the microbial-plant system of soybean cultivar Merlin and strains of nodule bacteria *Bradyrhizobium japonicum*, under optimal conditions, increased the crop yield to 4.43 t/ha, which is 2.11 t/ha higher compared to the control and 1.01 t/ha higher relative to the experimental option with carbamide fertilizer.

1 Introduction

Population interaction in ecology is an ecology-related area addressing the study of various levels of organization and interaction of living organisms in the environment. A number of patterns of biological interaction exhibit specificity, particularly when the interaction has a distinct impact on the survival of the partner [1].

For more than four decades, the evolutionary unique ability of plants of the *Fabaceae* family for symbiotic interaction with bacteria of the genera *Sinorhizobion*, *Rhizobium*, and *Bradyrhizobium* has drawn attention of the scientific community who study the mutual coexistence of bacteria and plants in order to develop energy-efficient highly productive agroecosystems. Scientific findings and practical knowledge about molecular interactions of objects can be used to regulate the living conditions of both plants and bacteria, and control genetic, agroecological, agrobiological, and agrochemical mechanisms to increase the efficiency of legume-rhizobial interaction.

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At present, the research in this area is of global relevance due to the crucial role of leguminous plants as agricultural crops.

Soy is a unique crop in terms of protein and oil characteristics; it is universal in terms of its application (food, fodder, technical, agrotechnical, medicinal) [2]. Among agricultural crops, this crop ranks second after wheat in the total mass of protein [3]. Soy protein concentrates (texturates, isolates, hydrolysates) are extensively used in the food industry [4]. Soybean is not among the traditional agricultural crops grown in the Kaliningrad region. However, statistical data show its stable involvement in the structure of crop production areas in the region [5]. This is due to the growing demand for soybeans in the domestic and foreign markets, which entails the expansion of crop production areas, an increased average soybean yield, and increased prices for soy and soy products. The structure of the areas varies depending on the region of soybean cultivation, being increasingly concentrated in the European part of Russia.

In the formation of legume agroecosystems, pre-sowing inoculation of seeds with virulent strains is commonly used. An increased yield and quality of plant fruits has repeatedly demonstrated the practical significance of this agricultural method. However, diverse and unstable conditions of the edaphotope for phytocenoses do not allow the use of unambiguous algorithms for controlling the effectiveness of the symbiosis of plants and rhizobia. Even in the same year, rhizobia of different cultures can be exposed to completely different moisture and temperature conditions, which significantly changes the level of nitrogen fixation [6].

The aim of the study was to evaluate the effectiveness of the control of the productivity of *Glicyne max* (L.) Merill agrophytocenoses as part of the initiative research into Resource potential of agricultural plants in the context of symbiotic population interactions (subject code No. 01.33.001-2).

2 Object and methods of study

The goal of the study was to make a comparative assessment of the effect of bacterial fertilizers and their combinations with mineral fertilizers on quantitative and qualitative indicators of the yield of soybean cultivar Merlin in accordance with the experimental design presented in Table 1.

Production, agrotechnical, and short-term experiment. Predecessor was winter wheat; 30 cm wide row sowing method; seeding rate of 75–80 pcs/m^2; sowing was performed on May 13, 2021. Edaphotop of the agroecosystem represented soddy-weakly podzolic gleyic light loamy soil, with medium reaction close to neutral, high and very high content of mobile phosphorus and exchangeable potassium.

Table 1. Experimental design

I	Soybean	*Bradyrhizobium japonicum* inoculation	(*control*)
II	Soybean	*Bradyrhizobium japonicum* inoculation	($(NH_4)_2SO_4$ – 35.7 kg a.i./ha)
III	Soybean	*Bradyrhizobium japonicum* inoculation	($(NH_2)_2CO$ – 41.4 kg a.i./ha)

Soybean cultivar Merlin of Austrian selection; mid-early; plant with unlimited growth; approved for cultivation in the territory of the Russian Federation since 2008. Preparation of seeds for sowing included monoinoculation with a bacterial preparation based on the *Bradyrhizobium japonicum* species.

Observations were performed using conventional research methods. Formation of a symbiotic apparatus was studied through monitoring soil moisture to a depth of 60 cm; the

leaf area index (LAI) [7], plant structure, biological yield, and seed quality were estimated. The quality of soybean grain in 2001 was assessed using the Inframatic 9500 NIR Grain Analyzer in compliance with GOST 13586.3-83. Grain. Acceptance rule and sampling method.

3 Results

Phytocenosis productivity is assessed by the amount of nitrogen available to plants. The sources of nitrogen for plants are soil nitrogen, biological and industrial nitrogen [8, 9]. Inoculation is performed to form a highly efficient nitrogen-fixing symbiotic apparatus – a legume-rhizobial system to fix atmospheric nitrogen from the air (N_2) and convert it into the ammonium form (NH_4) [10-12] available for plants.

The field experiment showed that the option 'Soybean + inoculation + mineral fertilizers (35.7 kg a.i./ha of ammonium sulfate)' is most productive in terms of nodule formation; on average, up to 8 pieces per plant at the stage of plant branching; up to 0.8 mm in diameter (Fig. 1) Nodule formation was affected by the mineral nitrogen fertilizers.

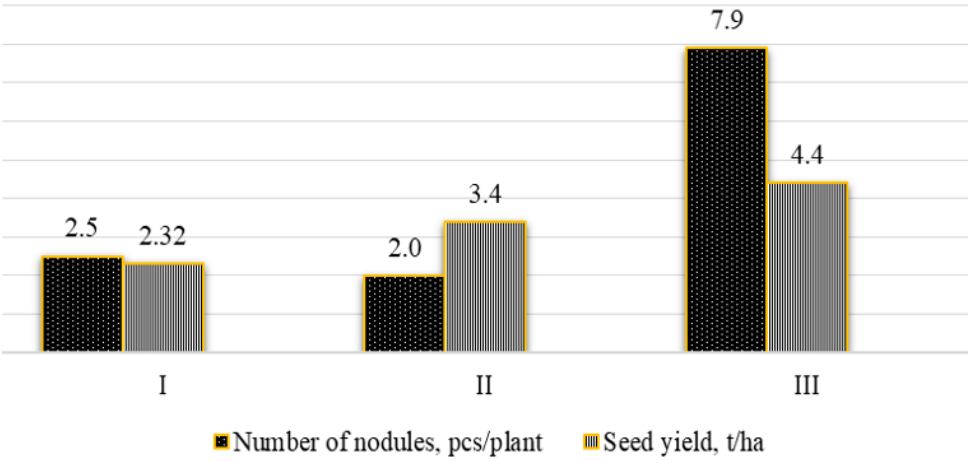

Fig. 1. Quantitative characteristics of the study

The quality of the grain is an important indicator for soybean cultivation, which determines the economic efficiency of the enterprise. Grain quality was assessed with regard to three indicators: fiber, protein, oil content (Fig. 2).

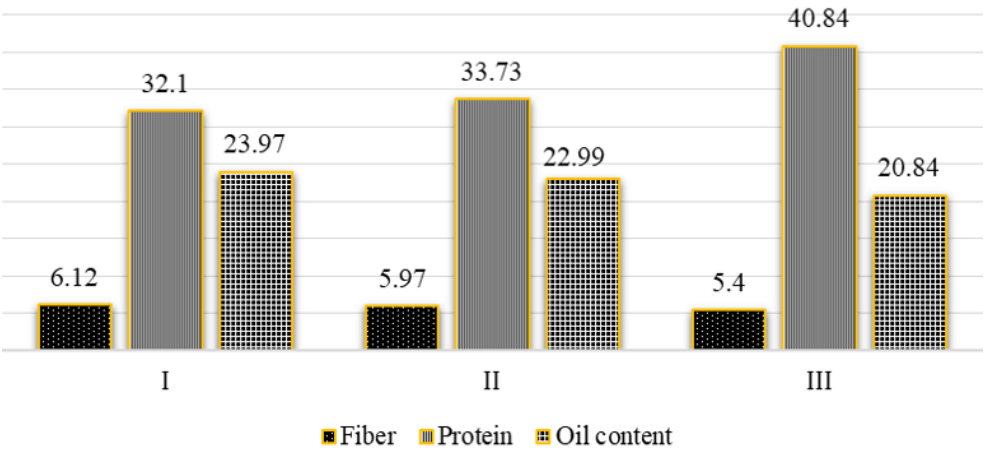

Fig. 2. Qualitative characteristics of soybean grain, %

In The experiments that employed inoculation and mineral fertilizers showed a higher protein content compared to the control. In this case, the higher the proportion of protein, the lower the proportion of oil content in seeds. This dynamic pattern indicates natural maturation of soybean seeds.

4 Conclusion

Control of the efficiency of microbial-plant systems of soybean and strains of nodule bacteria *Bradyrhizobium japonicum* stimulated formation of 2–8 nodules with a diameter of 0.4–0.8 mm in the plant rhizosphere. The number of active nodules was found to increase in the experimental option with a single application of mineral ammonium, sulfate fertilizer, in the budding phase. Processing of the experimental data by the statistical method showed strong relationships ∫=0.71 for the effect of the fertilizer system on quantitative indicators of the biological soybean seed yield. Experimental option No. 3 is most effective for the control of the productivity of soybean agrophytocenosis. Application of carbamide increased the yield to 4.43 t/ha, which is 2.11 t/ha larger compared to the control and 1.01 t/ha larger than that obtained in the experimental option with ammonium sulfate. The highest protein value in seeds was determined in experimental option No. 3; it amounted to 40.84%, which is 8.74% larger than that in the control and 7.11% larger than that in experimental option No. 2. The developed fertilizer system makes results in the profit of 173,439 rub/ha (2,069 $/ha as of 12.06.23), which exceeds the control by 102,400 rub/ha (1,221 $/ha).

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