THE EFFECT OF BIOSTIMULANTS ON THE FORMATION OF ROOT NODULE BACTERIA IN MUNG BEAN VARIETIES

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Abstract

This article presents the results of three-year field experiments conducted from 2022 to 2024, studying the dynamics of root nodule formation in "Durdona" and "Marjon" mung bean varieties and the influence of biostimulants on this process. The research demonstrated that the application of biostimulants Fitobiosol, Gumi–20, and Avangard Start significantly enhanced the activity of rhizobacteria and markedly stimulated the formation of root nodules.

Keywords: Biostimulant, Phytobiosol, Gumi–20, Avangard Start, mung bean, Durdona, Marjon, root nodules, rhizobacteria, symbiosis, development, nitrogen fixation, experiment, observation.

Introduction

In recent years, agro-technological measures aimed at ensuring ecological sustainability, restoring soil fertility, and increasing biological activity have gained significant importance in agriculture. In particular, the use of biostimulants rich in biologically active substances is recognized as a promising direction for activating plant growth physiology, improving root system function, and enhancing beneficial symbiotic interactions with microorganisms.

Leguminous crops such as mung bean stand out by forming root nodules with symbiotic bacteria belonging to the genus *Rhizobium*, which enable the fixation of atmospheric molecular nitrogen. Effective development of these nodule bacteria not only supports the nutrition of the plant but also contributes to the natural restoration of the nitrogen balance in the soil. Therefore, studying the number and quality of root nodules and the factors influencing their formation remains a vital scientific and technical task today.

Literature Review and Methodology

Soil fertility is one of the most important agrobiological factors ensuring high productivity of agricultural crops. The growth and development of plants largely depend on the quantity, diversity, and activity of nutrients and microorganisms in the soil, with these microbiological factors playing a key role in nutrient cycling within the soil. According to the literature, healthy

and fertile soil contains over 5 billion bacteria per gram, with beneficial microorganisms constituting the majority of this microbiota [4].
Beneficial microorganisms, especially nitrogen-fixing rhizobial bacteria, form symbiotic relationships with plant roots and enrich the soil with natural nitrogen through biological nitrogen fixation. Bacteria belonging to the genus *Rhizobium* form nodules on the roots of legumes such as mung bean, chickpea, and other legumes, converting atmospheric molecular nitrogen into a form accessible to plants through symbiotic interaction. This process demonstrates the effectiveness of biological methods in maintaining and enhancing soil fertility.
Following the cultivation of mung bean and chickpea, the number of microorganisms in the 0–30 cm and 30–50 cm soil layers increased significantly compared to the control. Specifically, the total bacterial count increased to 76.8–70.0 million/g and 54.7–48.4 million/g, nitrogen fixers to 78.1–77.8 thousand/g and 44.7–43.3 thousand/g, nitrifying bacteria to 86.5–82.2 thousand/g and 62.8–60.7 thousand/g, fungi to 68.1–66.3 thousand/g and 54.6–52.1 thousand/g, and actinomycetes to 58.7–54.4 million/g and 38.6–36.2 million/g, respectively. These results confirm the significant role of the root zone microflora of legumes such as mung bean and chickpea in activating soil microbial communities [2; p. 46].
Based on the above data, it can be concluded that using biostimulants to activate rhizobial symbiosis in mung bean varieties, increase the diversity of soil microorganisms, and develop ecologically sustainable agro-technologies is possible. This approach serves as a vital foundation for preserving soil fertility and ensuring the effective use of biological resources in agriculture.

Results and Discussion

Biostimulants are typically applied by spraying onto the leaves. Nevertheless, the natural phytohormones, vitamins, amino acids, and microelements contained in them enhance the overall metabolic activity of the plant. This, in turn, directs the flow of carbohydrates to the roots, resulting in the activation of the rhizosphere microflora. Through these processes, symbiotic relationships with nodule-forming bacteria are strengthened. To date, it remains a pressing task to thoroughly investigate this mechanism scientifically and to confirm it through experiments under natural agrobiological conditions.
In this study, the effects of biostimulants (Fitobiosol, Gumi–20, Avangard Start) on mung bean varieties Durdona and Marjon were examined at two different planting densities. The main focus was on the formation of root nodules, their developmental stages, and the level of bacterial populations. The results have practical importance for developing environmentally safe, biologically effective, and economically feasible technologies for mung bean cultivation.

Based on the experimental results from 2022 to 2024, the dynamics of root nodule formation in mung bean varieties were analyzed. The findings showed that nodule formation begins from the early seedling stage and sharply increases especially during the budding and flowering phases. During this period, the activity of rhizobacteria is high, leading to the formation of numerous nodules on the roots. This growth continues into the pod-filling stage; however, a slight decrease in the number and mass of nodules was observed during the maturation phase. This indicates that in the later stages of vegetation, as the nodules have fulfilled their primary biological functions, their activity naturally declines, and in some cases, the nodules degrade or lose their functionality.

During the flowering and pod-filling stages, the plant's demand for nitrogen is high, whereas this requirement decreases during the maturation phase. As a result, the need for nitrogen fixed by rhizobacteria diminishes, leading to a slowdown in nodule activity. The carbon compounds produced in the plant's leaves are redirected toward seeds and fruits during the final stages of vegetation. This shift causes changes in nutrient availability within the rhizosphere, which in turn reduces the activity of the nodule-forming bacteria.

Symbiotic relationships between the plant and Rhizobium bacteria are most active during the flowering and pod-filling phases. However, during the later stages of vegetation, this symbiosis naturally weakens, causing a decrease in the rate of nodule development. Environmental factors such as soil temperature, moisture, and others during the maturation phase can negatively impact the viability of nodule bacteria. This may result in the degradation or cessation of nodule growth.

Based on these observations, it was found that bioactive substances applied via foliar biostimulants positively affect nodule formation by influencing the root system through signal molecules, hormones, or metabolic exchanges. However, this effect becomes limited in the final stages of vegetation due to natural physiological processes.

The data obtained during the experiment were consistent across the years, with notably better development of nodule bacteria observed only in the 2024 trial. Statistical analysis of the results confirmed the reliability of the data (Table 1).

In 2024, for the Durdona variety in the control variant, at the beginning of the budding stage, the number of nodules corresponded to the seedling density and ranged from 14.5 to 13.3 nodules. With increased seedling density, the number of nodules decreased by 1.2. During the flowering stage, the number of nodules was 18.1–17.4, and in the pod-filling stage, it was 25.4–23.5, with nodule counts decreasing by 0.7–1.9 due to increased seedling density.

In the variant treated with the Fitobiosol biostimulator (4 l/t, 4 l/ha), the number of nodules at the beginning of budding was 30.1–27.2, depending on seedling density. Increased seedling density led to a reduction of 2.9 nodules. During flowering, the number of nodules was 43.4–

42.6, and during pod-filling, it was 51.3–50.7, with a decrease of 0.8–0.6 nodules due to higher seedling density.
For the variant treated with the Gumi–20 biostimulator (2.4 l/t, 1.8 l/ha), the number of nodules at the start of budding ranged from 27.6 to 25.8 according to seedling density, with a slight reduction of 0.4 nodules due to increased density. During flowering, the number of nodules was 39.5–36.2, and during pod-filling, it was 48.9–45.4, showing a decrease of 3.3–3.5 nodules corresponding to higher seedling density.
In the variant treated with Avangard Start biostimulator (1.5 l/t, 1.0+2.0 l/ha), the number of nodules at the budding phase was 31.2–29.4 according to seedling density, with a decrease of 1.8 nodules as density increased. During flowering, the nodule count was 48.7–45.1, and during pod-filling, it was 55.1–52.8, with reductions of 3.6–2.3 nodules due to increased seedling density.
The highest results were recorded in the Avangard Start-treated variant, where the number of nodules corresponded to seedling density and developmental stages, reaching 31.2–29.4, 48.7–45.1, and 55.1–52.8 nodules, respectively.

Table 1. Effect of biostimulators used in the experiment on the formation of root nodule bacteria in mung bean varieties, nodules per plant (2024).

No	Mung Bean Variety	Experimental Variant	Theoretical Seedling Density (thousand/ha)	Development Stages		
				Budding	Flowering	Pod formation
1	Durdona	Control	200	14,5	18,1	25,4
2			300	13,3	17,4	23,5
3		Fitobiosol	200	30,1	43,4	51,3
4			300	27,2	42,6	50,7
5		Gumi–20	200	27,6	39,5	48,9
6			300	25,8	36,2	45,4
7		Avangard Start	200	31,2	48,7	55,1
8			300	29,4	45,1	52,8
9	Marjon	Control	200	12,1	19,5	24,6
10			300	11,3	17,3	22,8
11		Fitobiosol	200	26,4	41,1	52,7
12			300	23,6	40,8	50,2
13		Gumi–20	200	24,2	37,4	46,1
14			300	22,8	34,2	41,4
15		Avangard Start	200	28,5	43,6	57,3
16			300	25,7	40,1	53,5

In the control variant of the Marjon variety, at the beginning of the budding stage, the number of nodules ranged from 12.1 to 11.3 per plant depending on seedling density. With an increase in seedling density, the number of nodules decreased by 0.8. During the flowering phase, the number of nodules was 19.5 to 17.3, and in the pod formation phase, the number ranged from 24.6 to 22.8, with a corresponding decrease of 2.2 to 1.8 nodules due to the increased seedling density.

In the variant treated with the Fitobiosol biostimulator (4 l/t, 4 l/ha), at the beginning of the budding stage, the number of nodules was proportional to seedling density and ranged from 26.4 to 23.6 per plant. An increase in seedling density resulted in a decrease of 2.8 nodules. During the flowering phase, the number of nodules ranged from 41.1 to 40.8, and during the pod formation phase, from 52.7 to 50.2, with decreases of 0.3 to 2.5 nodules observed due to the increased seedling density.

In the variant treated with the Gumi–20 biostimulator (2.4 l/t, 1.8 l/ha), at the beginning of the budding stage, the number of nodules ranged from 24.2 to 22.8 per plant, depending on seedling density. With an increase in seedling density, the number of nodules decreased by 1.4. During the flowering phase, the number of nodules was 37.4 to 34.2, and in the pod formation phase, it ranged from 46.1 to 41.4, with a corresponding decrease of 3.2 to 4.7 nodules due to increased seedling density.

In the variant treated with the Avangard Start biostimulator (1.5 l/t, 1.0 + 2.0 l/ha), at the beginning of the budding stage, the number of nodules ranged from 28.5 to 25.7 per plant depending on seedling density. An increase in seedling density led to a decrease of 2.8 nodules. During the flowering phase, the number of nodules was 43.6 to 40.1, and in the pod formation phase, it ranged from 57.3 to 53.5, with a corresponding decrease of 3.5 to 3.8 nodules due to increased seedling density.

In this variety as well, the highest results were recorded in the variant treated with Avangard Start (1.5 l/t, 1.0 + 2.0 l/ha), where the number of nodules corresponded to seedling density and development stages at 28.5–25.7, 43.6–40.1, and 57.3–53.5 nodules, respectively.

Throughout the experiment, it was confirmed that the influence of various biostimulators on the formation and number of nodules in the studied mung bean varieties was positive. In the control variants of the Durdona and Marjon varieties, the number of nodules was relatively low across developmental stages, averaging between 11.3–14.5 nodules at budding, 17.3–18.1 nodules at flowering, and 22.8–25.4 nodules at pod formation. An increase in seedling density in these variants caused a decrease in nodule number by 0.7 to 2 nodules.

In variants treated with Fitobiosol, Gumi–20, and Avangard Start biostimulators, the number of nodules significantly increased at all stages compared to the control. Notably, Avangard Start showed the highest results. In the Durdona variety, plants treated with Avangard Start had nodule counts of 31.2–29.4 at budding, 48.7–45.1 at flowering, and 55.1–52.8 at pod formation, relative to seedling density. In the Marjon variety, the numbers were 28.5–25.7, 43.6–40.1, and 57.3–53.5 nodules, respectively, which were higher than those observed with other biostimulators and in control variants.

Summary:

Based on the results of experiments conducted from 2022 to 2024, the Avangard Start biostimulator ensured the highest microbiological activity in the rhizosphere of the Durdona and Marjon mung bean varieties. In particular, in the Marjon variety during the podding stage, the number of bacteria was high (57.3 nodules per plant), exceeding the control variant by an average of 16 to 33 nodules per plant across all three growth stages. The greatest difference was observed during the flowering and podding phases, with a significant increase in microbiological activity. This indicates the high efficiency of Avangard Start in enhancing microbial activity in the plant root zone and improving the symbiotic environment. The slightly higher bacterial count in the Marjon variety reflects its greater sensitivity to biostimulators and its higher microbiological potential.

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