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BIOPREPARATIONS ROLE IN THE MANAGEMENT OF THE GREEN AND DRY MASS YIELDS OF ALFALFA (*MEDICAGO SATIVA* L.)

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SUMMARY

Alfalfa (*Medicago sativa* L.) is a perennial herbaceous legume widely cultivated to provide high-quality forage in the form of hay and silage. Animal husbandry should acquire a stable base of feed production support, as its further development and efficiency depend on the feed base, and the industry needs new approaches. The provision of livestock with high-protein feeds determines the need for intensive cultivation of perennial legumes, like alfalfa (*Medicago sativa* L.), which is a significant addition to protein in animal feeds. Perennial legumes should occupy 2–3 times the area in hectares, and crop rotation should ensure the sustainability of arable land and crop production. During field crop rotation, perennial grasses produce 0.15 to 0.6 tons of feed units per hectare and provide livestock with up to 1/4 of all feeds. Perennial legumes' vital role is clear; in particular, alfalfa has great forage and agrotechnical importance in increasing soil fertility. In previous years, the trend has been the transition from chemical plant protection to biological measures with organic cultivation technology.

Keywords: Alfalfa (*M. sativa* L.), leguminous crops, forage production, high-protein feeds, biological preparations, foliar treatment, green and dry mass yield

Key findings: Exogenous application in the beginning of alfalfa (*M. sativa* L.) flowering with biological preparations (Organit P + Organit N + Biodux + Foliar) and external top dressing are possible to enhance the herbage density, generative stems, stress resistance, and plants' preservation. The biological products Organica S + Foliar and foliar application boost the foliage and green and dry mass yields.

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INTRODUCTION

Alfalfa (*Medicago* L.) belongs to the legume family Leguminosae Endl. and comprises approximately 60 species. It is a recognized effective biological meliorant, serving as an excellent precursor for various crops by suppressing soil-borne pathogens and enriching the soil with essential plant nutrients through nitrogen fixation. In Kazakhstan, two species of alfalfa—common alfalfa (*Medicago sativa* L.) and variable alfalfa (*Medicago varia* Mart.)—have predominant cultivation in the eastern, southern, and northern regions. The total cultivation area ranges from 80,000 to 110,000 hectares, with a tendency toward an annual expansion (Absattar *et al*., 2015).

In recent decades, there may be a single year when the livestock industry's feed requirements have been fully complete, ensuring the realization of the genetically determined productive potential of bred livestock. Currently, the cost and availability of feeds are relevant to meet the needs of the growing global population (Mendoza *et al.*, 2019). Past research confirmed continuous improvement in crop yields and improving animal husbandry efficiency requires cultivation of perennial legumes. It is one of the key factors and recommended strategies for mitigating the climate change effects, contributing to an enhanced soil fertility by fixing atmospheric nitrogen (Sollenberger and Kohmann, 2024). Urazaliev and Kireev (2002) reported cultivation of perennial grasses for five years in the fallow field of a grain-fallow crop rotation had a significant impact on the humus content of the rainfed gray soil. Under grasses in their first year, the humus content was 1.13%; however, after five years, the humus content increased to 1.27% under barley crop.

A large-scale intensification of crop production has been evident for the past 70 years on the European continent, causing significant variations in the soil's available nitrogen (N), phosphorus (P), and other nutrients. Therefore, scientists should focus on the new approaches in agriculture on increasing crop diversity and the share of perennial legumes in crop rotation, as perennial legumes act as nitrogen accumulators and can serve as a full-fledged alternative to mineral fertilizers. The legumes capture nitrogen from the atmosphere and effectively enrich the soil. Perennial legumes are the best precursors for grain crops, subsequently providing an increase in yield of up to 0.5–0.6 tons per hectare (Recous *et al.*, 2018).

Crop rotation has the highest accumulation of post-harvest residues, straw, and root crops, as achieved in a four-field rotation with a fallow land of 3.4 tons per hectare (Seminchenko, 2021). The amount of nitrogen entering the soil with straw and post-harvest residues appeared to be 49.8 kg/ha in an eight-month rotation. The highest amount of biological nitrogen accumulated was under alfalfa (*Medicago sativa* L.). Alfalfa cultivation demonstrates a profitability of 16% as compared with other perennial leguminous crops (Osterholz *et al*., 2020).

The above-ground parts (leaves, stems, and flowers) of perennial leguminous plants, such as alfalfa (*M. sativa* L.), clover (*T. pratense* L.), and sainfoin (*O. viciifolia* Scop.) are rich in phytochemicals (tannins and saponins), which are powerful substances for strengthening the immune system in animals. This indicates an increase in the quality of fodder based on perennial leguminous crops (Butkute *et al*., 2018). In biochemical composition, alfalfa hay surpasses various other feeds. The 100 kg hay of alfalfa has digestible protein (11.6 kg), calcium (1.77 kg), phosphorus (0.22 kg), and carotene (4.5 g). Biologically, alfalfa is irreplaceable in agronomic and reclamation terms, especially on saline soils.

In maintaining ecological situations, increasing soil fertility, forming safe agroecosystems, and providing subsequent crops in crop rotation with nitrogen, a vital element that plants require in large quantity, perennial leguminous plants play a key role. For instance, the three-year presence of alfalfa in crop rotation allowed the accumulation of up to 13–17 tons of post-harvest residues per hectare, with nitrogen (280–300 kg), phosphorus (63–80 kg), and potassium (66–120 kg) content in soil (Bastaubayeva *et al.*, 2023). The need to develop environmentally friendly and balanced farming methods using organic resources and microbial inoculants in the form of biological products is relevant today. Studies on rhizobacteria and fungal strains, with their exceptional diversity and ability to adapt to various extreme conditions that stimulate plant growth, are becoming increasingly crucial due to their numerous advantages over chemical fertilizers and pesticides (Pandey, 2020).

This study highlights the relevance of using certified biopreparations to enhance alfalfa productivity under the sharply continental. The results contribute to the development of sustainable and organic forage production systems adapted to arid environments. The sharply continental climate of Northern Kazakhstan imposes specific requirements on the agritechnology of growing perennial leguminous crops, which directly affects the green and dry mass yields. The presented study proposes the use of biopreparations during the vegetative and flowering stages of the alfalfa crop. This research aims to study the effect of foliar application of biopreparations on the green and dry mass yields of alfalfa (*M. sativa* L.) crop.

MATERIALS AND METHODS

Study site and meteorological conditions

The following research relied on cultivation technology with the application of biological preparations in alfalfa. It ran from 2022 to 2024 at the experimental field of the LLP-Kokshetauskoe Experimental and Production Farm, Shagalaly Village, located in the northern part of the steppe zone of the District Zerendinski, Akmola Region, Kazakhstan. The meteorological conditions in 2022–2024 revealed characteristics of sharp continentality. According to the meteorological data, the total precipitation in 2022 was 311 mm, which was nearly equal to the long-term average norm (315.5 mm). The highest rainfall occurred in July (77.0 mm) and June (49.6 mm), while the lowest values appeared in September (6.6 mm) and April (5.5 mm) during 2022. The year, classified as dry, had a hydrothermal coefficient (HTC) of 0.73.

In 2023, the total precipitation was 300.2 mm, close to the long-term average (305.7 mm). Precipitation during the cold period (September-March) had a significant impact on the accumulation of productive moisture reserves in the soil, amounting to 118.3 mm. The deficit of atmospheric precipitation was 1.6% compared with the long-term norm (120.2 mm). During the 2024 growing season, the highest recorded precipitation was 275.4 mm. The first four months of this year saw 253.6 mm of precipitation, which exceeded the long-term average (95.3 mm). The year was characteristically wet, with a hydrothermal coefficient of 1.5. During the growing season, in 2022, the precipitation was 193 mm, 2023 (168.8 mm), and 2024 (275.4 mm) (Table 1).

The soil consisted of ordinary chernozem with a medium humus content, with the humus horizon depth ranging from 25 to 27 cm and an average humus content of 4.01%. In the arable layer, the nitrate nitrogen was 17.9 mg, available phosphorus at 8.6 mg, and exchangeable potassium at 67.0 mg per 100 g of soil. Thus, the nitrogen content was medium, phosphorus was low, and potassium was high. The soil texture was heavy loam in the arable horizon with a bulk density of 1.19 g/cm³ and an average bulk density of 1.30 g/cm³ in the one-meter layer. The moisture content at the point of stable wilting was 12%–13%.

Field research comprised three repetitions, and in the experiments, the agronomic practices were zonal. The area of each experimental plot was 20 m², with a randomized placement of plots. Using a fallow crop served as a predecessor. The field observations, counts, and analyses followed the generally accepted methodology (Dospekhov, 1985).

Cultivation technology

The sowing proceeded with both row and wide-row, with a row spacing of 70 cm. During the active growth phase and plant maturation, the biological preparations applied were spraying

Table 1. Meteorological conditions during 2022–2024 (Shagalaly Village weather post, Kazakhstan).

Month	Precipitation (mm)		Air temperature (°C)	
	Long-term average	2022–2024	Average long-term	Long-term average
2022				
January	12.3	11.6	-16.0	-12.4
February	13.3	18.5	-14.2	-9.2
March	16.3	4.7	-6.0	-9.0
April	19.0	5.5	+4.5	+8.5
May	32.8	15.7	+12.2	+13.6
June	41.0	49.6	+16.7	+17.7
July	67.0	77.0	+19.0	+19.9
August	36.5	44.1	+17.1	+16.7
September	25.2	6.6	+11.0	+13.0
October	24.3	13.6	+3.7	+4.3
November	15.8	29.6	-5.1	-8.3
December	13.1	7.3	12.5	11.5
Total	316.6	283.8		
2023				
January	12.5	12.0	-16.4	-12.7
February	14.0	10.7	-14.0	-12.6
March	16.4	11.3	-5.8	-3.1
April	18.7	1.2	+4.9	+4.1
May	34.1	15.8	+12.4	+12.7
June	46.0	30.8	+17.1	+18.7
July	46.0	20.5	+17.1	+22.8
August	37.8	35.5	+16.8	+18.0
September	25.6	66.2	+11.3	+12.3
October	26.5	35.1	+3.6	+5.5
November	15.8	31.3	-5.6	-0.6
December	12.3	29.8	-13.3	-13.4
Total	305.7	300.2		
2024				
January	12.9	30.6	-15.8	-14.3
February	13.2	8.6	-14.2	-14.9
March	16.2	10.5	-5.9	-5.9
April	18.5	18.6	+4.8	+8.2
May	32.7	65.1	+12.0	+9.1
June	44.2	65.0	+17.0	+20.9
July	63.9	67.5	+18.8	+19.5
August	39.7	56.0	+17.1	+17.1
September	27.0	21.8	+12.0	+10.5
October	26.7	15.5	+9.0	+2.9
November	18.9	15.8	-5.7	-5.1
December	13.7	8.5	-13.4	-8.2
Total	327.6	353.0		

with the TU-2291ANION/RUS-2000 installation, which was compatible with the tractor of the 1.4 N class. The treatment continued at the stage of maximum development of the vegetative organs, depending on the duration of the phenological phases and the growing season of the crop, usually on the 45th–48th day after regrowth. The scheme of the experiment comprised five options, i.e., a) control, b) Bio-Sleep BW + Foliar, c) Orgamica S + Foliar, d) Organit N + Organit P + Biodux + Foliar, and e) Foliar.

Biopreparations used in the experiment

Organit P: A safe and effective mobilizer of nutrition that improves mineral nutrition of plants by increasing the bioavailability of phosphorus and potassium. Approved for use in organic farming as per the standards of the International Accredited Certification Bodies for Organic Production, USDA-NOP standard, and EU regulations No. 1165/2021.

Organit N: Improves nitrogen nutrition and growth indicators of the crops due to the ability of bacteria *Azospirillum zeae* to fix atmospheric nitrogen and convert it into forms suitable for plant consumption. Approved for use in organic farming according to the standards of the International Accredited Certification Bodies for Organic Production, USDA-NOP standard, and EU regulations No. 1165/2021.

Biodux: A growth regulator based on the ability of a complex of biologically active polyunsaturated fatty acids from the soil fungus *Mortierella alpina* to create a prolonged and non-specific systemic resistance in plants and activate growth and biological processes. Approved for use in organic farming according to the standards of the International Accredited Certification Bodies for Organic Production, USDA-NOP standard, and EU regulations No. 1165/2021.

Bio-Sleep BW: intestinal contact insecticide, effective against lepidopterans—cotton bollworm, pyralid moth, codling moth, cabbage moth, and meadow moth. Approved for use in organic farming according to the standards of the International Accredited Certification Bodies for Organic Production, USDA-NOP standard, and EU regulations No. 1165/2021.

Orgamica S: Spores in the preparation germinate, becoming vegetative cells that multiply and colonize the treated plant surfaces (roots, stems, leaves, and reproductive organs). Growth suppression in fungal and bacterial pathogens succeeds through the action of metabolites (enzymes and antibiotic substances) produced. Approved for use in organic farming according to the standards of the International Accredited Certification Bodies for Organic Production, USDA-NOP standard, and EU regulations No. 1165/2021.

Fertigrain Foliar: It promotes vegetative growth, eliminates microelements deficiencies, enhances crop productivity, and increases the plant's ability to recover. The composition of the Fertigrain Foliar preparation includes zinc (0.75%), manganese (0.50%), boron (0.10%), iron (0.10%), copper (0.10%), molybdenum (0.02%), and cobalt (0.01%) (Kalin *et al.*, 2023).

Research procedure

The object of the study was alfalfa (*Medicago sativa* L.) of the local variety Kokshe, included in the State Register of Breeding Achievements of Kazakhstan since 1968. Field trials commenced during the third year of crop development. The onset of phenological phases—including bloom start, full bloom, and maturation start—entailed determination through regular visual observations. These stages correspond to the phenological descriptions provided by Enriquez-Hidalgo *et al*. (2020) for forage legumes. Plant safety (preservation) assessment succeeded by comparing plant density (plants/m²) at the beginning and end of the growing season. Counts proceeded within fixed quadrats, with the percentage of surviving plants calculated accordingly. Fresh biomass yield measurement occurred in the field at harvest. A plant sample from each plot, when collected, underwent drying in a convection oven at 65 °C for 36 h to determine the dry matter content and calculate the dry biomass yield, following the procedure described by Rimi *et al*. (2010). For various parameters, the recorded data's analysis used the STATISTICA version 10, www.statsoft.com. The variability values resulted from calculating the means, the coefficient of variation (V%), the standard error (Sx), and correlation analysis.

RESULTS AND DISCUSSION

Phenological phases

In the alfalfa study years of 2022–2024, spring arrived relatively early for the growth and development of alfalfa plants compared with the long-term data. Therefore, regrowth for all the studied variants occurred between April 19 and 24. As presented in Table 2, the regrowth starting with foliar treatments was evident in the variants 'Bio-Sleep BW + Foliar' and 'Organit P + Organit N + Biodux + Foliar,' with the start of the usual regrowth around April 18–19 based on three years' data. For the variants 'Control' and 'Fertigrain Foliar,' regrowth occurred on April 20–21, observing the latest regrowth on April 21–24 in the variant 'Orgamica S + Foliar.' Among the studied variants, the first flowering period was noticeable on the 45–47 days and maturity on the 89–91 days for the combination of 'Organit P + Organit N + Biodux + Foliar.' In the case of variants 'Bio-Sleep BW + Foliar' and the 'Control,' the first flowering appeared on the 47–49 days, and maturity occurred on 92–95 days. However, the full maturity of the alfalfa crop was notable between 112 and 118 days. With its biological characteristics, rapid alfalfa blooming can negatively affect the green and dry mass yields and the quality of feed biomass (Wolabu *et al.*, 2023).

Exogenous application

Plant height effect on the total mass

The plant height is an important sign that determines the total mass of a plant (Kharkov *et al*., 1986) and detects the variations in the presented experiments based on the alfalfa crop study years. The plant height varied over the years depending on the precipitation and temperature conditions. With the foliar treatment of the alfalfa crop in the early-flowering phase, the average plant height in 2022 ranged from 40.3 (Bio-Sleep BW + Foliar) to 57.4 cm (Organit P + Organit N + Biodux + Foliar), in 2023 from 33.0 (Bio-Sleep BW + Foliar) to 39.0 cm (Orgamica S + Foliar), and in 2024 from 57.3 (Organit P + Organit N + Biodux + Foliar) to 62.6 cm (Bio-Sleep BW + Foliar) (Table 3).

Intensive growth of the alfalfa plants was visible in 2022 and 2024. In 2024, a significant amount of precipitation (65.0 mm) was abundant during the growing season compared with the long-term average (44.2 mm), and a relatively high humidity manifested during June and July. In 2023, the variability in plant height was notable due to insufficient rainfall compared with the long-term data. Over the years of research, the greatest plant height with foliar treatments at full bloom materialized in 2022 with 'Organit P + Organit N + Biodux + Foliar' (58.0 cm), in 2023 with 'Orgamica S + Foliar' (39.0 cm), and in 2024 with Foliar (64 cm). The slight growth retardation observed at full flowering under 'Bio-Sleep BW + Foliar' and 'Orgamica S + Foliar' treatments, compared with the control, may be due to their biological function. 'Bio-Sleep BW' acts as a bioinsecticide, while 'Orgamica S' serves as a microbial protectant. Unlike growth stimulants ('Organit N,' 'Organit P,' and 'Biodux'), these biopreparations are not specifically applicable to enhance vegetative growth, which may explain the reduced shoot elongation in these variants.

Table 2. Duration of the phenological phases and the growing season of the crop depending on the treatment options (days).

Options	Day of regrowth	Period from the beginning of regrowth (days)		
		Bloom start	The beginning of maturation	Full maturation
Control	20-21.04	47-49	92-94	116-118
Bio-Sleep BW + Foliar	18-19.04	47-49	93-95	115-117
Orgamica S + Foliar	21-24.04	46-48	90-92	113-116
Organit P + Organit N + Biodux + Foliar	18-19.04	45-47	89-91	112-115
Fertigrain Foliar	20-21.04	46-48	91-93	116-118

Table 3. Effect of biologics treatment on alfalfa plant height (cm) during 2022–2024.

Options	20th day of regrowth	Bloom start	Full bloom	Maturation start	Full maturation
2022					
Control	25.8	44.0	44.5	44.5	43.5
Bio-Sleep BW + Foliar	26.0	40.3	41.0	41.0	40.2
Orgamica S + Foliar	24.0	41.0	42.0	41.5	41.0
Organit P + Organit N + Biodux + Foliar	24.6	57.4	58.0	58.0	58.0
Fertigrain Foliar	27.0	43.0	43.5	43.5	43.0
V (%)	4,66	15,54	15,18	15,37	16,21
Sx (%)	0,53	3,14	3,11	3,14	3,27
2023					
Control	26.5	33.2	34.2	34.2	34.5
Bio-Sleep BW + Foliar	25.3	33.0	34.0	34.0	34.0
Orgamica S + Foliar	23.8	39.0	39.0	39.0	39.0
Organit P + Organit N + Biodux + Foliar	27.5	31.7	32.5	32.5	32.5
Fertigrain Foliar	24.0	31.0	32.0	32.0	32.0
V (%)	6,27	9,42	8,07	8,07	8,05
Sx (%)	0,71	1,42	1,24	1,24	1,24
2024					
Control	26.4	61.4	62.5	63.0	63.0
Bio-Sleep BW + Foliar	27.0	62.6	63.0	63.0	62.0
Orgamica S + Foliar	25.2	62.6	63.0	63.0	63.2
Organit P + Organit N + Biodux + Foliar	27.3	57.3	58.0	60.0	61.0
Fertigrain Foliar	26.8	62.5	63.5	63.5	64.0
V (%)	3,08	3,72	3,65	2,26	1,85
Sx (%)	0,37	1,02	1,01	0,63	0,52

With foliar treatments throughout the growing season of alfalfa, a positive correlation was remarkable between the plant height at the beginning of flowering and plant density (r = 0.5) (Figure 1) and green mass yield (r = 0.7) (Figure 2). This revealed the green mass yield and plant density have interrelations with plant height. The presented research has established that with foliar feeding throughout the growing season of alfalfa, the highest plant preservation rate resulted in the variants Foliar and 'Organit P + Organit N + Biodux + Foliar.' They were 1.6% higher than the preservation observed in the variant control.

In the alfalfa plant growth during the study years 2022 and 2023, an increase in plant density emerged. With spraying crops during the beginning of the flowering phase, the treatment combination 'Organit P + Organit N + Biodux + Foliar' (18.7 plants/m²) and Foliar (18.8 plants/m²) showed the highest plant density, while the lowest plant density appeared in the variant control (17.7 plants/m²) and 'Orgamica S + Foliar' (17.5 plants/m²). The number of generative stems per plant (ranging from 5 to 15) depends on the plant's age, the area of nutrition, and soil fertility (Dyukova *et al*., 2013).

Economically valuable traits

The results showed that with foliar treatments throughout the growing season of alfalfa, biopreparations 'Organit P + Organit N + Biodux + Foliar' affected the formation of generative stems (7.8 stems per plant) and Foliar (7.9 stems per plant) compared with the variant control (6.5 stems per plant). Foliar spraying of the alfalfa crop with biopreparations positively influenced the intensive growth and accelerated plant development, stimulating the production of a more powerful habitus with resistance to unfavorable growth conditions. By the first mowing, the treated crops, due to increased growth and stress resistance, preserved plants

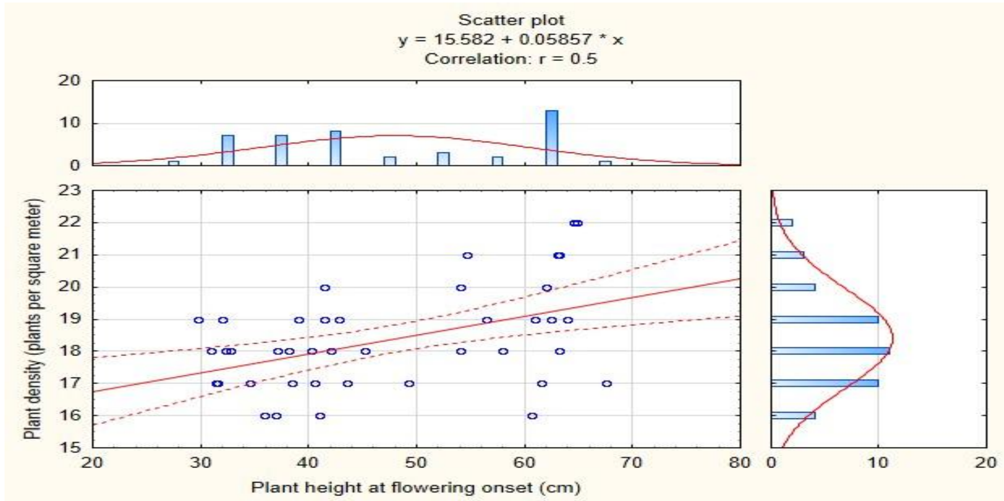

Figure 1. Influence of plant height on plant density.

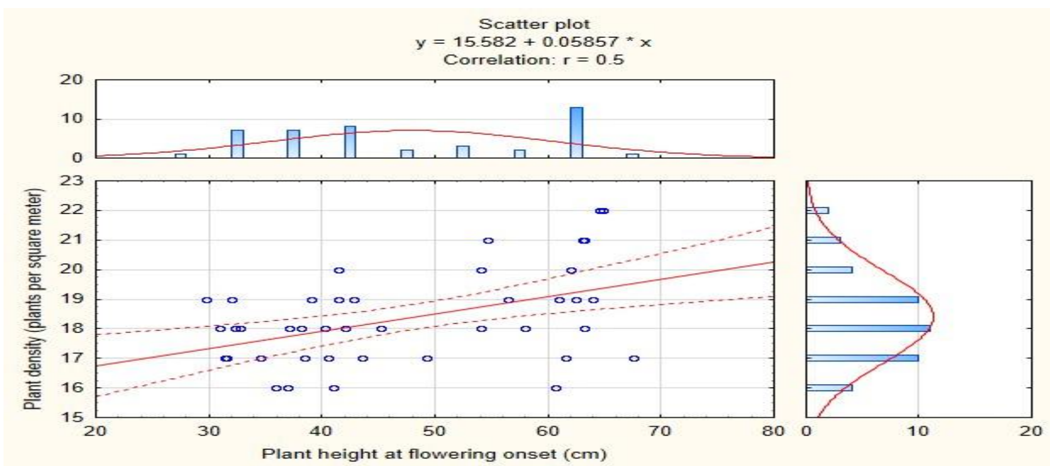

Figure 2. Influence of plant height on green mass yield.

at the rate of 65% to 79% (Table 4). The same signs of plant stress resistance were evident in past studies using biologics based on the *S. meliloti* GR4 strain (Bellabarba *et al*., 2023).

The presented economically valuable signs of culture, depending on the biological products, which revealed an average degree of variation, ranged from 10% to 14%. The leaves and inflorescences stand out from other parts of the plant for their high nutritional values. Foliage is one of the key factors determining the nutritional value of a plant variety. In this study's observations, the leafiness of the alfalfa plants during the beginning of the flowering phase with foliar treatments stood out, with the treatments 'Orgamica S + Foliar' (42.1%) and Foliar (42%), which are higher than the control by 0.95% and 0.7%, respectively.

In forage crops, the main criterion is the productivity of green mass, with foliar treatments throughout the growing season. Overall, the green mass in the treatments Foliar (161.1 g/m²) and 'Orgamica S + Foliar' (159.1 g/m²) was higher than the control by 7.4 and 5.4 g/m², respectively. The variant

Table 4. Influence of biopreparations on economically valuable traits of the crop during 2022–2024.

Options	Plant stand density (pcs/m^2)	Number of generative stems per plant (pcs)	Plant preservation (%)
Control	17.7	6.5	66.2
Bio-Sleep BW + Foliar	18.0	7.1	78.4
Orgamica S + Foliar	17.5	6.6	79.1
Organit P + Organit N + Biodux + Foliar	18.7	7.8	79.8
Fertigrain Foliar	18.8	7.9	70.0
V (%)	3.23	9.10	8.29
Sx (%)	0.26	0.29	2.77

Table 5. Evaluation of economically and biologically significant traits depending on the use of biopreparations during 2022–2024.

Options	Leafiness (%)	Productivity		
		Green mass (g/m^2)	Dry mass (g/m^2)	Seeds (g/m^2)
Control	41.7	153.7	45.7	2.25
Bio-Sleep BW + Foliar	41.6	154.0	46.0	2.5
Orgamica S + Foliar	42.1	159.1	46.7	3.0
Organit P + Organit N + Biodux + Foliar	41.5	152.8	45.0	2.6
Fertigrain Foliar	42.0	161.1	48.0	2.6
$LSD_{0.05}$	-	1.3	0.4	0.2

'Bio-Sleep BW + Foliar' showed the same results as with the control, while the treatment 'Organit P + Organit N + Biodux + Foliar' was lower than the control by 1.0 g/m². It is possibly because of an earlier transition to generative development, which may have limited vegetative biomass accumulation at the time of harvest. The introduction of trace elements, particularly cobalt (Co) and molybdenum (Mo), contributed to an increase in the green mass yield of the alfalfa (Toktarbekova *et al*., 2020).

The results further revealed that the dry mass yield was directly proportional to the green mass yield. The best treatments with foliar treatments during the growing season were Foliar (48 g/m²) and 'Orgamica S + Foliar' (46.7 g/m²), recording as higher than the control by 2.3 and 1.0 g/m², respectively. However, the differences among the values obtained with the variants, control (45.7 g/m²), 'Bio-Sleep BW + Foliar' (46 g/m²), and 'Organit P + Organit N + Biodux + Foliar' (45 g/m²) were nonsignificant (Table 5).

In the experiment with foliar treatment of alfalfa crop, correlation analysis between the productivity of green mass and the plants' foliage showed a negative relationship. Organic agriculture uses agroecological and agrochemical approaches in its activities. Presently, the assessment of the environmental impact of pesticides and their behavior and side effects has become as crucial as considering the varied composition of local components of agroecology (Castillo-Díaz *et al*., 2022).

No chemical pesticides, synthetic fertilizers, or other substances should be a proposal for use. Bio-manufacturers should replace chemicals with drugs of natural origin, which include the drugs used in this study. In particular, the complex of biologically active polyunsaturated fatty acids of the soil fungus *Mortierella alpina* contained in the biological product Biodux was able to form and activate the growth and biological processes in crop plants. Kalmykova (2021) reported pre-sowing treatment of tomato seeds and foliar treatment of plants with modern growth regulators Energia-M and Biodux stimulate the plant growth and development, increase productivity, and positively affect the plants' stress resistance to adverse environmental conditions.

The Agrotonic biological product based on organic waste, raw materials from animal and plant components, and fungal strains contains all the macronutrients for dry matter for plants—nitrogen (3.7%), phosphorus (2.6%), potassium (4.5%), and meso- and trace elements (calcium, magnesium, sulfur, boron, molybdenum, iron, copper, manganese, zinc, and cobalt). The use of biological products reduced the contamination of winter wheat plants by 16.7% to 27.1% and increased crop yields by an average of 7.7% to 24.0%, as compared with the control (Zudilin *et al*., 2020).

The biopreparations Orgamica S, Organit N, and Organit P can fix atmospheric nitrogen and convert it into forms suitable for plant consumption due to bacterial colonies *Bacillus megaterium* and *Bacillus amyloliquefaciens.* Likewise, they can improve plant nutrition by increasing the bioavailability of phosphorus and inhibit the growth of harmful objects through special enzymes. The Bio-Sleep BW bioinsecticide, based on the fungus strain *Beauveria bassiana* with a consumption rate of 1.5–3 liters/ha, proved effective in leguminous crops by up to 60%. It is efficient against larvae, aphids, and other insects, which can compete with and replace the expensive chemical plant protection measures.

The use of Fertigrain Foliar micro-fertilizers containing trace elements, i.e., zinc (0.75%), manganese (0.50%), boron (0.10%), and molybdenum (0.02%), positively influenced the structure of the crop yield elements. In the presented study, the Fertigrain Foliar affected the plant height in alfalfa (64 cm) compared with the control (63 cm). Similarly, it increased the yield of green mass (161.1 g/m^2) and dry mass (48.0 g/m^2) versus the control with green and dry mass yields of 153.7 and 45.7 g/m^2, respectively. Double spraying of the wheat crop during the growing season with the biostimulant Fertigrain (Foliar) positively altered the plant height by 21% and increased grain yield (16.7 t/ha) against the control (5.2 t/ha), and the protein yield increased from 12.44% to 14.26% (Al-Juthery *et al*., 2018).

The foliar top dressing with Fertigrain Foliar and Juice Argentum Agro preparations in the cultivation of grafted seedlings of grape cultivars Sibirkov and Varyushkin was effective. It was notable that the length of the mature part of the growth increases from 21 to 54 cm in the cultivar Varyushkin, and from 28.7 to 90.3 cm in the cultivar Sibirkov. The use of foliar treatment with Fertigrain Foliar ensured an increase in the yield from 12.5% to 25.1% in the grape cultivar Sibirkov, and from 4.4% to 18.4% in the cultivar Varyushkin (Titova and Avdeenko, 2024).

CONCLUSIONS

In alfalfa crops, the use of biopreparations 'Organit P + Organit N + Biodux + Foliar' and Fertigrain Foliar during the beginning of flowering enhanced the herbage density and generative stems on plants. Increased stress resistance and plant preservation were obvious, ranging from 65% to 79% (Organit P + Organit N + Biodux + Foliar), and foliage was up to 42.1% in the variant 'Orgamica S + Foliar.' The best effect on plant height and green and dry mass yields was remarkable with the use of Fertigrain Foliar. Thus, for alfalfa stands in the second and third years of life, foliar treatments during the beginning of flowering with biopreparations 'Orgamica S + Foliar' and Fertigrain Foliar emerged as recommendable for obtaining stable green and dry mass yields in alfalfa.

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