# Methods of increasing the productivity of various varieties and hybrids of variegated alfalfa in the conditions of arable farming biologization

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**Abstract.** Two-year studies of variegated alfalfa (*Medicago varia* Mart.) of the following varieties and hybrids were carried out: Pastbischnaya 88, Taisia, Agnia VIC, 506 and SGP, as well as observations of their reaction to inoculation. Strains of nodule bacteria *Sinorhizobium meliloti* were used as inoculants: SHM1-105, 415, A-1, A-5, and a control variant without inoculation. As a result of research, it was revealed that the minimum length of stems in 2021 was fixed in the Pastbischnaya 88 + 415 variant, and amounted to 12.5 cm, in 2022 — Taisia with A1 and SHM1-105, 8.8 cm each. The maximum length of stems in 2021 was marked by a hybrid 506 in a combination of A1 and SHM1-105 strains, the indicator was 40.4 and 40.3, respectively, in 2022 — Agnia VIC + A5, 28 cm. In 2021, the Pastbischnaya 88 variety with the strain SHM1-105 turned out to be the most competitive, its share prevailed over the unseeded admixture, and reached 54.8%, in 2022 variant Agnia VIC + 415 was distinguished with this indicator, with a mass fraction of 65.45%. The positive effect of inoculation was revealed, the best symbiotic varietal microbial systems were determined. The strain of nodule bacteria 415 is marked by a complex effect on all varieties of variegated alfalfa. According to the yield of dry weight (3.3 t/ha on average), the Taisia variety and the SGP hybrid were distinguished.

## 1 Introduction

Today, special attention is paid to the issues of arable farming biologization and the crops grown must meet its requirements. Promising in many aspects, variegated alfalfa (*M. varia*) has a powerful phytomeliorative effect: it increases soil fertility, reduces the cost of

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agricultural products, contributes to resource conservation due to its longevity and diversity. It has a high yield and good feed quality. Alfalfa, in the presence of symbiotic relationships with nodule bacteria, contributes to the accumulation of biological nitrogen in the soil [10].

In feed production, alfalfa is of high economic, environmental, and operational importance: it significantly contributes to solving such tasks as eliminating protein deficiency in feed and reducing their cost due to its productive longevity and providing high-protein feeds without introducing expensive nitrogen fertilizers [5].

Nevertheless, growing alfalfa can be economically unprofitable if it is grown without inoculation of seeds. In his works O.G. Rapina [7] notes that legumes from potential nitrogen collectors can become consumers if preparations of nodule bacteria are not used on the culture, which in turn leads to a decrease in soil fertility. Inoculation of alfalfa seeds promotes the development of symbiotic activity, which improves the nitrogen nutrition of plants, and, consequently, increases crop yields [8]. Inoculation also contributes to an increase in diazotrophy, an increase in adaptive properties and green mass yield. Nitrogen fixation by nodule bacteria is an important process that provides plants with bound nitrogen and its accumulation in the soil [1].

An important factor in the agriculture greening is the use of nitrogen entering the soil and plants as a result of atmospheric fixation with the help of microorganisms, which in modern realities is one of the tasks, along with providing livestock with high-quality feed. Here it is necessary to note the ecological safety of the supply of plants with bound nitrogen, which excludes the option of contamination of soil, reservoirs, and products with nitrates. In addition, microbial nitrogen fixation is carried out mainly at the expense of solar energy and avoids the cost of energy feedstock [4].

The quality of a plant-microbial symbiotic system development with nodule bacteria significantly affects the yield of legumes. Alfalfa also has a positive effect on soil fertility: it is able to absorb moisture and nutrients that are difficult for other plants to reach from the deep soil layers due to a powerful root system, strengthens the arable soil layer, and also acts as protection against water and wind erosion, which is important in modern agriculture [2].

Nodule bacteria, being symbionts, spread in the soil, interacting with certain types of legumes, and their almost ubiquitous distribution indicates a high degree of adaptability to various soil and climatic conditions. Bacterial cells after the destruction of nodules enter the soil and exist, like other soil microorganisms, due to various organic substances. Nodule bacteria are able to lead a symbiotic and saprophytic lifestyle [6].

For the good development of plants provided by symbiosis, a certain set of environmental conditions is necessary and, if the latter are unfavorable, the effectiveness of the mutual existence of the plant-microbial symbiotic system will be low, despite the high virulence, competitive ability, and activity of the microsymbiont [3].

For the development of nodules, optimal humidity is required at the level of 60-70% of the FMC (field moisture capacity), and its minimum limit is 16%. If the value is lower and there is not enough moisture, the bacteria do not multiply, but they do not die, and can remain inactive for a long time. With a lack of moisture, the already formed nodules die off. In areas with insufficient moisture, legumes often develop without forming nodules.

Since the reproduction of bacteria does not occur in the absence of moisture, in case of dry spring, inoculated (artificially infected) seeds must be put deeper into the soil. Interestingly, nodule bacteria of soils in arid climates are more resistant to drought than bacteria of soils in humid climates. This shows their ecological fitness [10].

To date, for the sustainable development of feed production in the country and in Karelia in particular, it is necessary to develop effective ways to create long-term highly productive herbage with the inclusion of modern alfalfa varieties.

## 2 Materials and Methods

Studies have been conducted to study the effect of inoculation of strains on varieties and hybrids of variegated alfalfa to determine the best plant-microbial systems for the productivity of green mass in the Republic of Karelia

On the basis of the experimental areas of the Laboratory of Agricultural Technologies "Vilga" KarSC RAS, two-factor field experiement was laid in 2021 and 2022, on June 26 and July 7, respectively.

The material for the study is varieties and hybrids of variegated alfalfa, which are factor A: Pastbischnaya 88, Agnia VIC, Taisia and hybrids: SGP and 506 (Lucya) and strains of *Sinorhizobium meliloti* for inoculation, factor B: A1, A5, 415, SHM1-105. On the control plots, sowing was carried out with untreated seeds (without inoculation). As a control, due to its adaptive ability to abiotic stress factors, the Taisia variety (high cold resistance, drought resistance, resistance to waterlogging of the soil in the spring), superior to other domestic varieties, was determined.

The area of the accounting plot is 10 sq.m., the repetition is 4 times, the placement of options is systematic. Accounting of the yield is continuous from the entire plot in the budding phase. The mowing mode is twofold, in the first year of life — one-fold.

According to the mechanical composition, the soil of the experimental site is medium loamy, the subtype is sod-podzolic, slightly acidic with a $pH_{sol}$ 5.9 , the content of mobile phosphorus $P_2O_5$ is 85.9 mg/100 g; exchangeable potassium $K_2O$ is 41.2 mg/100 g of soil.

The field season of 2021 was marked by a sharp shortage of moisture in June and July (12 and 55 mm less than the average annual), against the background of temperatures exceeding the average annual by 7.2 and $4^0$C, respectively, the HTC of these months was only 0.78 and 0.46, which characterizes the months as very dry. Despite this, the growing season HTC was 1.8, due to the excessive moisture content of May and August, their precipitation data exceeded the average value by 13 and 104 mm, which affected seedlings and crop formation in the first year of grass life.

The growing season of 2022 in terms of heat and moisture availability turned out to be more favorable than the previous one, temperature indicators were close to the average long-term data and exceeded them by 1.6, 1.9, and $3.8^0$C in June, July, and August, respectively. In terms of moisture availability, these months exceeded the monthly average by 6, 16, and 22 mm, respectively, which characterizes the field season as heat-supplied and excessively moistened, the HTC for the season was 2.8 (Fig.1).

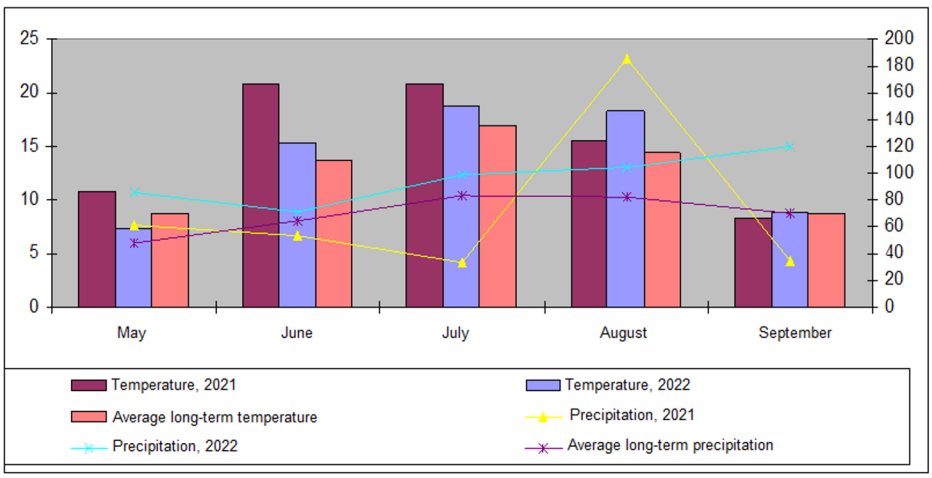


**Fig. 1.** Weather conditions of the 2021 and 2022 field seasons.

## 3 Results and Discussions

Inoculation with nodule bacteria influenced the intensity of alfalfa shoot formation. On the control plots, the number of shoots in the first year of life was 80-292 pcs/m$^2$ in 2021 and 268-856 pcs/m$^2$ in 2022 (Fig. 2).

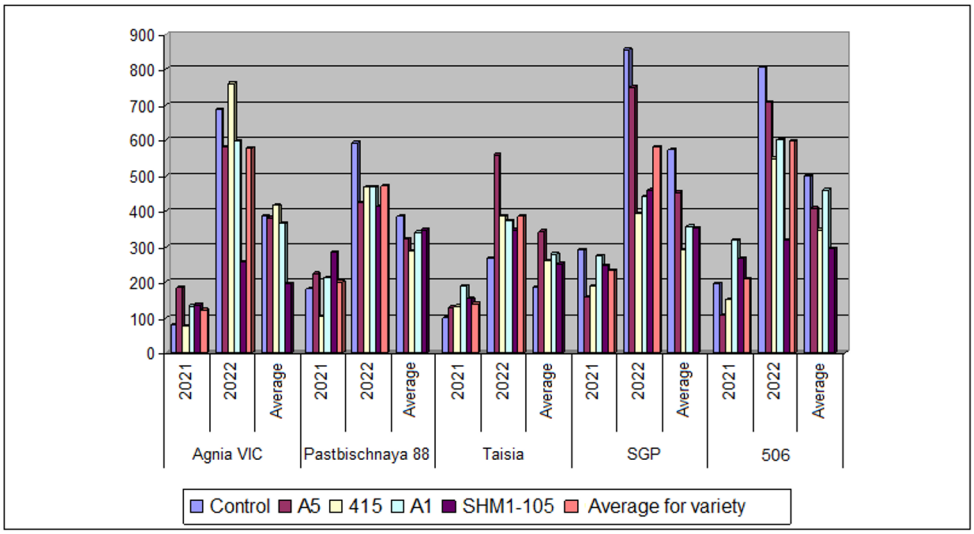


**Fig. 2.** Density of herbage, pcs/m$^2$ in the first year of life.

In the variants treated with nodule bacteria, the density varied depending on the strain and did not show a significant deviation from the control 76-284 pcs/m$^2$ in 2021 and 256-760 pcs/m$^2$ in 2022. Probably, the control variants exceed the inoculated ones due to moisture, which is so necessary at the germination stage. It is also worth noting here that the growing season of 2021 was characterized by a sharp shortage of moisture with an increased temperature component, which affected all indicators of quality and crop formation in the first year of herbage life, 2022 turned out to be more favorable for the beginning of vegetation of phytocenoses.

Analyzing the shoot-forming ability of variegated alfalfa, it can be noted that there were significant varietal differences in the length of stems (Fig. 3): in the control variant in 2021, alfalfa plants of the Agnia VIC variety surpassed Taisia, Pastbischnaya 88, and SGP by 14.7, 14.1, and 5.1 cm, respectively, while yielding to the hybrid 506 – by 1.8 cm.

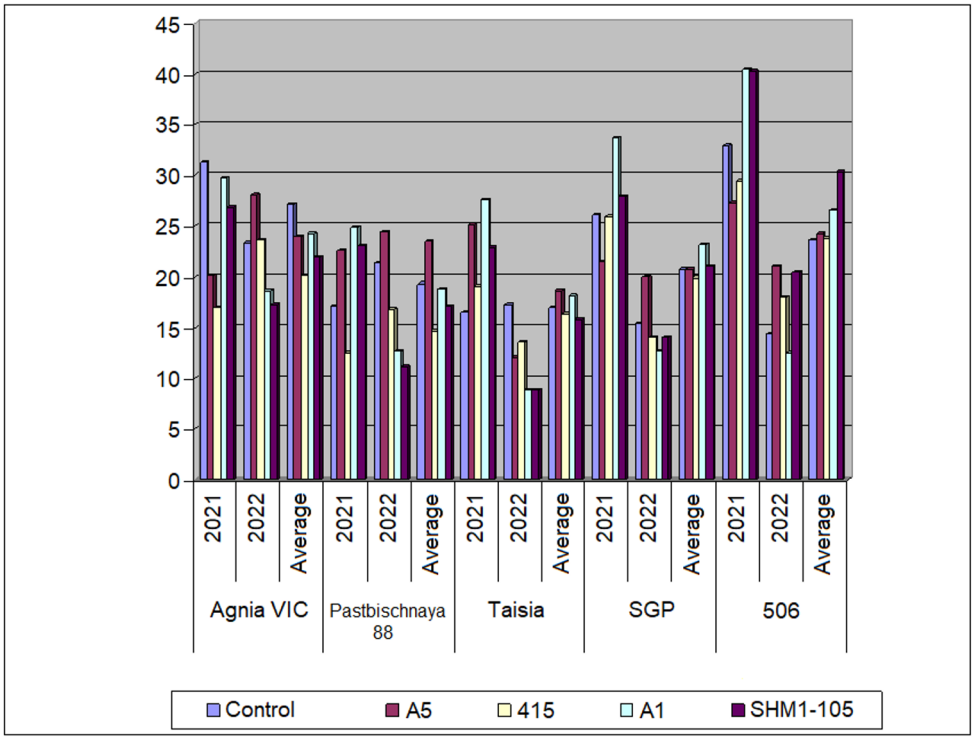


**Fig. 3.** The length of the variegated alfalfa stems first year of life in 2021 and 2022, cm.

Pastbischnaya 88 and Taisia in all variants were characterized by minimal values relative to other varietals and hybrids. In the context of the variety, the effect of strains on the length of stems showed an ambiguous result: in the arid conditions of 2021, inoculated variants had lower indicators than the control, since nitrogen-fixing bacteria can inhibit the symbiont plant under unfavorable conditions.

In the experiment of 2022, the Taisia variety also showed minimum values (8.8-17.3 cm), the best in terms of the tops, as in the previous experiment, it was Agnia VIC (17.2-28 cm).

In the course of research, the effect of inoculation by nodule bacteria on the ability of alfalfa plants to resist the colonization of agrophytocenosis by weeds was evaluated. The analysis of the botanical composition of grass stands indicates the stability of the studied species in these environmental conditions, their competitive power (Fig.4).

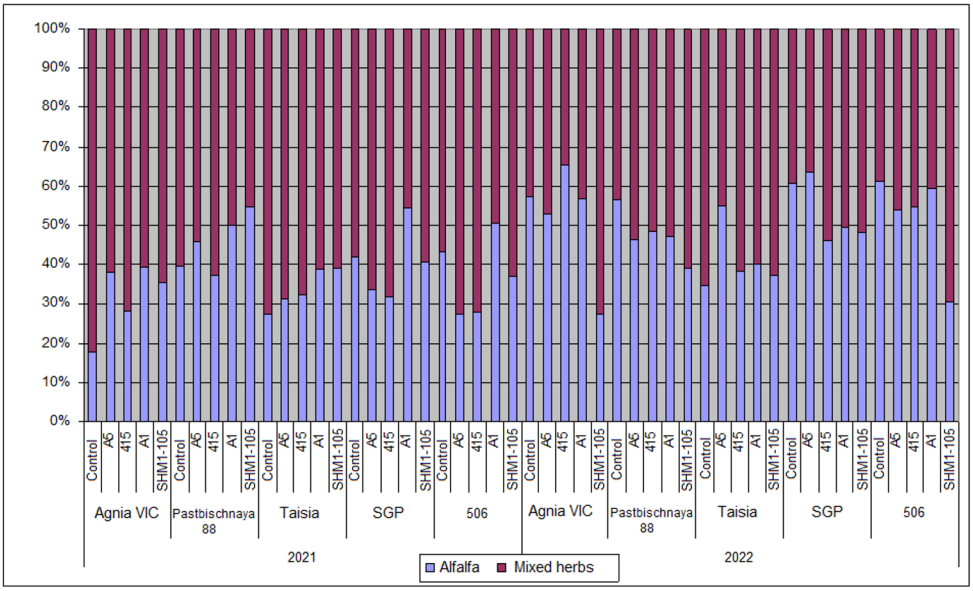


**Fig. 4.** The content of botanical and economic groups in the first year of herbage life, % in 2021 and 2022.

In the first year of life, alfalfa develops rather weakly and slowly, and the data of the herbage of the first year of life in 2021 and 2022 vary greatly with one another under the effect of meteorological conditions. The quantitative composition of phytocenoses was influenced by the heat and moisture supply of field seasons.

The share of variegated alfalfa in the botanical composition of herbage in 2021 accounts for 17.8-54.8% in the control variant with Agnia VIC and Pastbischnaya 88 with inoculation of SHM-1-105, respectively. The field season of 2022 is characterized by a higher ratio of variegated alfalfa to impurity, so its minimum proportion was 27.2% (Agnia VIC with strain SHM-1-105), and the maximum 65.4% was noted in this variety, but with inoculation with strain 415.

The largest number of planted grasses in 2021 is noted in control variants, without significant differences in varieties and varies from 56.5 to 82.2%, in 2022 the maximum proportion of mixed grasses was recorded when treated with strain A5 in all varieties (38.8-72.5%), and separately, phytocenoses with SHM-1-105 with all strains of rhizobacteria 51.7-72.5%.

The effect of the studied strains on the yield of the green mass of the tested varieties and hybrids was statistically significant (Table 1).

**Table 1.** Yield of dry mass of the first year of plant life, t/ha.

| Variety (hybrid) | Year | control | A5 | 415 | A1 | SHM-1-105 | average for variety |
|---|---|---|---|---|---|---|---|
| Agnia VIC | 2021 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | **1.2** |
| | 2022 | 3 | 2.8 | 3.3 | 2.1 | 3.2 | **2.9** |
| | Average | 2.1 | 2 | 2.2 | 1.6 | 2.2 | |
| Pastbischnaya 88 | 2021 | 1.2 | 1.1 | 0.9 | 1.1 | 0.9 | **1** |
| | 2022 | 2.8 | 3.3 | 3.6 | 2.7 | 2.7 | **3** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Average | 2 | 2.2 | 2.3 | 1.9 | 1.8 | |
| | 2021 | 1 | 1.1 | 1.3 | 1 | 1 | **1.1** |
| | 2022 | 3.5 | 4 | 3.3 | 3.2 | 2.7 | **3.3** |
| Taisia | Average | 2.2 | 2.6 | 2.3 | 2.1 | 1.8 | |
| | 2021 | 1 | 1 | 1.2 | 1.1 | 0.9 | **1.1** |
| | 2022 | 3.4 | 3.3 | 3.6 | 3.3 | 3.1 | **3.3** |
| SGP | Average | 2.2 | 2.2 | 2.4 | 2.2 | 2 | |
| | 2021 | 1 | 1 | 1.2 | 1.4 | 1.2 | **1.2** |
| | 2022 | 2.5 | 1.8 | 2.2 | 2.2 | 2.1 | **2.2** |
| 506 | Average | 1.8 | 1.4 | 1.7 | 1.8 | 1.6 | |
| average for preparation | 2021 | **1.1** | **1.1** | **1.1** | **1.1** | **1** | |
| | 2022 | **3** | **3.1** | **3.2** | **2.7** | **2.8** | |
| $LSD_{05}$ | 2021 | | | | | | 0.9 |
| | 2022 | | | | | | 1.76 |

In the conditions of 2021, the maximum yield was noted in the Taisia variety inoculated with strain 415, and amounted to 1.3 t/ha of dry mass. On average, according to the varieties, regardless of the preparations used, Agnia VIC and hybrid 506 were distinguished, their productivity reached 1.2 t/ha of dry mass. Among the strains, the best indicator is in 415 - 1.2 t/ha. SHM1-105 was characterized by minimum values for all varieties, not exceeding the control ones.

The growing season of 2022 is characterized by the best yield indicator, as in the previous year, for the Taisia variety, but with the A5 strain – 4.1 t/ha. In terms of varieties, on average, Taisia and SGP hybrid are in the lead, with a productivity of 3.3 t/ha of dry mass. As in the previous experiment establishment, strain 415 stood out from the rest, providing on average, regardless of the variety, a yield of 3.2 t /ha.

## 4 Conclusion

In the conditions of the Republic of Karelia, varieties of variegated alfalfa respond positively to inoculation by strains of nodule bacteria for a number of economically useful traits.

Even in the first year of life, variegated alfalfa is able to form yields of dry mass up to 3.3 t/ha (SGP+A5), which is important in economic realities. The work carried out objectively shows the peculiarities of variegated alfalfa development in the first year of life, the formation of herbage under the effect of external factors, namely, meteorological indicators. Alfalfa varieties are selective against strains of nodule bacteria, which is confirmed by data on changes in productivity. Plant-microbial systems are suitable for the cultivation of alfalfa on a green mass in the conditions of Karelia: variety Taisia + A5 and hybrid SGP + strain 415.

At this stage, the research has not been completed, the work will continue, since alfalfa is an average-year species, and more time and observations are required to obtain a deeper analysis.

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