Productivity of nitrogen fixation by perennial legumes in the conditions of the Novgorod region of the North-West of Russia

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Abstract. Data on the study of nitrogen-fixing ability of various species and varieties of meadow legume plants are presented. It has been experimentally proved that the formation, symbiotic apparatus and the accumulation of biological nitrogen, and, consequently, the share participation in the agrophytocenosises of the legume component, and the productivity of meadow grass stands are greatly influenced by the species, variety, features of the ontogenesis of the legume plant, as well as the conditions of plant growth. Due to symbiotic fixation on medium-acid soils of heavy mechanical composition in the first two years of their life, about 84 kg of nitrogen per 1 ha were accumulated by meadow clover of Carmine variety. Such a symbiotic apparatus provided forage from the main cut for hay without additional mineral fertilizers in the range of 5.4–5.6 tons of dry weight per hectare with a share of clover—about 33% in the 1st year and more than 60% in 2nd year of life.

1. Introduction
An important role in increasing the productivity of meadowlands and resource conservation in forage production is played by the biological source of nitrogen. For this, legume-grass meadow grass stands are created.

The amount of biological nitrogen fixed by legumes is more dependent on the activity of symbiotic bacteria [1, 2]. The more actively nodule bacteria work, the more favorable the conditions, the higher the effect of nitrogen fixation. Biological nitrogen not only contributes to an increase in the yield of agrophytocenosises, but also has a positive effect on the ecological situation in the region. Such biological nitrogen is used both by the plant itself and by related species. Legumes play an important role in the biologization of agriculture [3, 4]. Due to the enrichment of the soil with organic substances and biological nitrogen, they increase soil fertility and are valuable precursors in the crop rotation system. Perennial legumes are of exceptional interest for the production of nitrate-free products in crop production [5, 6, 7].

Of great importance in the accumulation of biological nitrogen is the selection of species and varieties of legumes [8, 9].

The purpose of the research was to study the nitrogen-fixing ability of various species and varieties of perennial legume plants sown in a mixture with associated grass components in the conditions of the Novgorod region.

The research objectives included:
1) determination of the yield of legume-grass grass stands by years of research;
2) analysis of the formation of nodules on the roots of various species and varieties of legumes by years of their life;
3) the study of the dynamics of the accumulation of biological nitrogen by legumes.

2. Methods and materials
The experimental part of the study of the nitrogen-fixing ability of various species and varieties of perennial legume plants in the Novgorod region was carried out on legume-grass meadow grass stands from the 1st to 3rd year of life during 2016–2018.

The following legume plants were included in legume-grass agrophytocenosises: meadow clover of varieties: Sedum and Carmine, hybrid clover of Lujanin variety, birdsfoot deer vetch of Gelsvis variety, Easterngalega of Gale variety.

The control and background in the experiment was a mixture of meadow fescue grass of Suydinskaya variety, timothy grass of Leningradskaya–204 variety and awnless brome of Dragon variety.

The experiment was carried out on a medium acid derno-podzolic soil of heavy mechanical composition.

Observations, yield accounting were carried out according to the methods of the All-Russian Feed Research Institute named after V.R.Williams [10, 11]. Accounting for productivity in the experiments was carried out by the mowing method in the phase of complete sweeping of the panicle of grain crops, the initial blossom of legumes (2011). The analysis of nodules on the roots of legumes and the accumulation of biological nitrogen were determined by the method suggested by P. Vavilov. and G.S. Posypanova [12].

3. Results and discussion
The accumulation of biological nitrogen and, consequently, the fractional participation of the legume component in the agrophytocenosises, and the productivity of meadow grass stands are greatly influenced by the species, the variety of the legume plant, ontogenesis, the age of the legume culture, as well as the conditions of plant growth.

So, the largest number of nodules formed on the roots of legumes of the first year of life (Table 1). A more powerful symbiotic apparatus was formed in clovers. From 80 to 90 nodules were formed on one plant.

Meadow clover of Sedum and Carmine varieties per 1 g of root formed about 115–134 pieces of nodules. As a result of studying the accumulation of biological nitrogen by legumes and cereals, it was found that this process was most intensive in agrophytocenosises with meadow clover Carmine in the first two years of life (figure 1).

Due to symbiotic fixation, it accumulated 72.9–83.9 kg of nitrogen per 1 ha, which corresponds to 48.2–57.5% of the total yield from the harvest.

Table 1. Change in the number of nodules formed and nitrogen-fixing ability in legumes by years of life.

| Grass stands            | Year of life | Productivity, CM from 1 ha | The number of nodules per 1 g of root, pcs. | % of symbiotic fixation |
|-------------------------|--------------|---------------------------|------------------------------------------|------------------------|
| Background + meadow clover | First        | 4.9                       | 134.0                                    | 36.9                   |
| Suedum                  | Second       | 4.6                       | 73.8                                     | 46.8                   |
| -                       | Third        | 4.8                       | 28.7                                     | 4.8                    |
| Background + meadow clover | First        | 5.6                       | 115.7                                    | 48.2                   |
| Carmine                 | Second       | 5.4                       | 105.6                                    | 57.5                   |
| -                       | Third        | 6.0                       | 42.5                                     | 27.0                   |
In the subsequent years of the life of clovers, due to the completion of the ontogenesis cycle, their symbiotic activity began to decline. By the 3rd year of life, the number of nodules per 1 g of root decreased by 2.7–4.7 times and amounted to only 25.1–42.5 pcs. By this year of life, the share of clovers in meadow grass stands has decreased significantly. Clovers accounted for only 7.7–21.3% of the total harvest mass. Compared to the previous year, nitrogen fixation of meadow clover of Carmine variety decreased by 2.5 times and amounted to about 33 kg of biological nitrogen per 1 hectare. The minimum intensity of nitrogen fixation was observed in meadow clover of Sedum variety. In the third year of life, it fixated only 4.5 kg of nitrogen per 1 ha, or 4.8% of the total yield from the harvest.

In contrast to juvenile clovers, the birdsfoot deer vetch of average age by the second and third years of life experienced an improvement in symbiotic activity. Almost five times as many nodules were formed on one plant of birdsfoot deer vetch in the second year of life than in the previous year, and in the third year–by 1.4 times and amounted to 26 nodules or about 65 nodules per 1 gram of root.

That is, by the 3rd year of life, birdsfoot deer vetch has formed more nodules than meadow clover and hybrid clover. This symbiotic activity of birdsfoot deer vetch reflected in its share in the grass stands: in the first mowing, the birdsfoot deer vetch accounted for about 15%, in the second–for more than 33%, and in the third–the ratio of the legume plant accounted for about half of the harvest. This year, due to symbiotic fixation, birdsfoot deer vetch accumulated 13.4 kg of nitrogen per 1 ha, which corresponds to 13% of the total yield from the harvest.

The functioning of the symbiotic apparatus is greatly influenced by the conditions for the growth of legumes. Due to unfavorable soil conditions, Eastern galega formed an ineffective symbiotic apparatus in all years of its life. Nodules formed only on individual plants. This directly affected the low crop productivity of the grass stand with the participation of Eastern galega.
4. Conclusion

Thus, as a result of a three-year observation of nitrogen fixation of various species and varieties of perennial legume plants, it has been experimentally proven that the appearance of the symbiotic apparatus and the accumulation of biological nitrogen and, consequently, the share of legume plants in agrophytocenosises and the productivity of meadow grass stands are greatly influenced by the species, variety, features of the ontogenesis of the legume plant, as well as the conditions for the growth of legumes.

On medium-acid soils of heavy mechanical composition, meadow clover Carmine had a clear advantage in the operation of the symbiotic apparatus. In the first two years of life, about 81 nodules or 115 pieces per 1 g of root were formed on one clover plant of this variety. Due to symbiotic fixation, it accumulated 72.9–83.9 kg of nitrogen per 1 ha, which corresponds to 48.2–57.5% of the total yield from the harvest. This circumstance favorably affected the share of clover in the total mass of the harvest, and, consequently, the quality of the forage mass.

Such a symbiotic apparatus provided forage from the main cut for hay without additional mineral fertilizers in the range of 5.4–5.6 tons of dry weight per hectare with a share of clover–about 33% in the 1st year and more than 60% in 2nd year of life.

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