Formation of Legume-Cereal and Cereal Herbage Based on Festulolium Depending on the Nitrogen Nutrition Regime in the Leningrad Region

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Abstract. Studies of the formation of single-species cereal and binary legume-cereal herbage with the participation of festulolium were carried out in 2014-2017 on the experimental field of the St. Petersburg State Agrarian University. Density of standing of festulolium shoots was maximum in the first year of herbage use. In subsequent years, there was a decrease in shoot formation, which indicates its fragility. The percentage of festulolium both in single-species crops and in binary mixtures was high during the first year of use – 90.9–96.6% and 65.4–77.9%, respectively. In subsequent years, a decrease in the participation of festulolium in the harvest and a simultaneous increase in the content of seeded legumes were noted. Under the conditions of the Leningrad region, with the intensive use of herbage, single-species crops of festulolium provided the minimum yield of dry matter. Growing festulolium in a mixture with legumes has increased yields. The maximum yield was provided by a two-component herbage with meadow clover – 12.5 and 13.8 t/ha. The use of nitrogen fertilizers at a dose of N60 increased the yield of all the studied mixtures.

1. Introduction

In the Leningrad region, the priority area of agriculture is dairy farming. The economic efficiency of animal husbandry is determined by the provision of a sufficient amount of balanced high-quality feed. Perennial grasses are the main source of forage. At the same time, in recent years, there has been an intensive multi-mowing use of grass stands for harvesting haylage and silage. In the North-West of the Russian Federation, as well as in northern Europe, widespread cereal species in hayfields are the cocksfoot, meadow timothy, meadow fescue, and among legumes, meadow clover [1, 2]. However, they do not fully meet the requirements of intensification of production: insufficiently high content of carbohydrates, an extensive rate of regrowth after mowing [3, 4]. In this connection, it is necessary to select species capable of providing high-quality feed, high yields and at the same time resistant to adapted to local conditions. In recent years, many advanced farms have included in their mixtures a new hybrid of cereal fescue and ryegrass species – festulolium, which is characterized by a high sugar content, high yield, good regrow capacity, and high winter resistance. To obtain the most protein-balanced feed, it is necessary to grow it in grass mixtures with legumes [5, 6, 7, 8]. Along with meadow clover, such non-traditional species for the Leningrad region as alfalfa and birdsfoot trefoil are becoming
more and more widespread. The selection of the species composition of herbage, in which there would be no oppression of species, a decrease in the productivity of herbage and the quality of the crop is relevant.

According to many scientists, festulolium responds well to the application of nitrogen fertilizers in a dose of N120 [9]. The introduction of leguminous species into the mixture allows to provide festulolium with nitrogen fixed by legume species and to reduce the dose of mineral nitrogen.

2. Materials and methods
The study of the formation of legume-graminaceous herbage and grasses with the participation of festulolium during intensive use of hay was carried out in a two-factor experiment. Factor A - we studied the species composition of legume-cereal herbage in 5 variants:

1. Single-species sowing of festulolium, variety VNIIK 90 (100%)
2. Festulolium variety VNIIK 90 (50%) + meadow clover variety Dymkovsky (50%)
3. Festulolium variety VNIIK 90 (50%) + birdsfoot trefoil variety Vega 87 (50%)
4. Festulolium variety VNIIK 90 (50%) + variable alfalfa variety Solnyshko (50%)
5. Festulolium variety VNIIK 90 (50%) + Swedish clover variety Luzhanin (50%).

Factor B: study of these stands without the use of nitrogen fertilizers and with the application of nitrogen fertilizers at a dose of N60.

The plot area is 10 m², the replication is four times, the placement is randomized. The use of grass stands is intensive – three times. Fertilizers were applied before sowing at a dose of P60K90, as well as in spring and autumn after the last cut at a dose of P30K45. Nitrogen fertilizers were applied in the spring at a dose of N30 and after the first mowing with N30 according to the scheme.

The soil of the experimental site is soddy-podzolic heavy loamy, the content of mobile phosphorus is 141 mg/kg, mobile potassium is 118 mg/kg, pH is 6.8, the humus content is 2.36%.

Meteorological conditions during the years of research in 2015–2017 were characterized by good heat supply, the air temperature exceeded the average long-term indicators. The moisture supply varied from year to year. In 2015, a sufficient amount of precipitation fell only in July; in the remaining months, a lack of moisture was noted. 2016 was characterized as wet, only in May there was an insufficient amount of precipitation, in the remaining months the amount of precipitation exceeded the average annual indicators. In 2017, the amount of precipitation was close to the mean annual.

The counts and observations were carried out according to the methods of research with perennial grasses of VNIIK, statistical data processing - according to B.A. Dospekhov [10, 11].

3. Results and discussion
The density of herbage is determined by the biological characteristics of plants, the mode of use and the provision of environmental resources. With the age of herbage, a decrease in the shoot formation of the seeded species was noted. During the growing season, there is an increase in the density of herbage from the first cut to the third.

The highest density of festulolium in single-species crops was noted in 2015 – 2850 – 4885 pcs/m², however, already in 2016, there is a sharp decrease in shoot formation by 2.2 times without nitrogen fertilizers and 3.0 times when applying nitrogen fertilizers (table 1). In binary grass mixtures, the highest density of herbage was observed in variants with variegated alfa – 3330 and 3010 pcs/m². Next year, as in single-species crops, a decrease in the density of herbage by 1.6 – 3.1 times is observed. This is due to a decrease in shoot formation, primarily of festulolium. With the age of the herbage, the shoot-forming ability of the birdsfoot trefoil and variegated alfalfa increased, and the meadow and Swedish clover decreased, which is explained by the biological characteristics of the species.

The study of the dynamics of the species composition of herbage makes it possible to reveal the competitiveness of species, their productive longevity. The content of seeded species was high in the
use of herbage – 90.7 – 98.2% in 2015, 50.1 – 91.9% in 2016 and 50.3 – 95.3% in 2017 (table 2). That speaks about their high competitiveness in short-term use.

**Table 1.** Shoot-forming capacity of festulolium and leguminous species depending on nitrogen nutrition.

| Variant | 2015 | 2016 | 2017 |
|---------|------|------|------|
|         | 1 mow | 2 mow | 3 mow | 1 mow | 2 mow | 3 mow | 1 mow | 2 mow | 3 mow |
| No nitrogen fertilizers | | | | | | | | | |
| 1. Festulolium | 3355 | 3685 | 3495 | 1505 | 1465 | 1615 | 510 | 575 | 810 |
| 2. Festulolium + meadow clover | 2725 | 3220 | 3955 | 1105 | 1755 | 2690 | 1675 | 2025 | 2485 |
| 3. Festulolium + birdsfoot trefoil | 3070 | 4220 | 3710 | 1335 | 2000 | 2635 | 1730 | 1940 | 2530 |
| 4. Festulolium + variegated alfalfa | 3330 | 3440 | 4365 | 1220 | 1910 | 2700 | 1295 | 1560 | 2015 |
| 5. Festulolium + Swedish clover | 2725 | 3365 | 3835 | 1250 | 2015 | 2185 | 1300 | 1665 | 1805 |

Application of nitrogen fertilizers N60

|         | 2015 | 2016 | 2017 |
|---------|------|------|------|
|         | 1 mow | 2 mow | 3 mow | 1 mow | 2 mow | 3 mow | 1 mow | 2 mow | 3 mow |
| 1. Festulolium | 2850 | 4330 | 4885 | 910 | 2110 | 2270 | 560 | 645 | 1445 |
| 2. Festulolium + meadow clover | 2160 | 2470 | 3375 | 765 | 1435 | 2365 | 1295 | 1590 | 2360 |
| 3. Festulolium + birdsfoot trefoil | 2950 | 4010 | 3910 | 1840 | 2985 | 3770 | 2215 | 2455 | 2645 |
| 4. Festulolium + variegated alfalfa | 3010 | 3300 | 4205 | 1305 | 1625 | 2035 | 1990 | 2195 | 2495 |
| 5. Festulolium + Swedish clover | 2865 | 3710 | 4445 | 1510 | 2540 | 2855 | 1125 | 1235 | 1605 |

Analyzing the botanical composition of the studied herbage by year, we found that the percentage of festulolium both in single-species crops and in binary mixtures was high during the first year of use – 90.9 - 96.6% and 65.4 – 77.9%, respectively. With age, there is a decrease in the participation of festulolium to 57.8% without N and 78.2% with N in single-species sowing and to 16.8–44.0% without N and to 19.0–29.7% with N in binary mixtures in the 3rd cut in 2017. There was also a decrease in the content of the cereal species from the first cut to the third during all three years of research.

When studying the interaction of legumes and festulolium in binary mixtures, it was found that in the first year of use, the greatest participation of festulolium in the harvest was noted in the variants with birdsfoot trefoil and variegated alfalfa, however, by the second and third years of use, its amount increased in grass stands with meadow and Swedish clovers. This is due to the fact that birdsfoot trefoil and variegated alfalfa are mid-summer species and reach their maximum development in 2–3 years of use, therefore, in the initial period, festulolium occupies a dominant position. While clovers are juvenile species and their maximum participation is noted in the first year of use. Due to the fact that festulolium has the same developmental rhythm, the competition between species increases. The use of nitrogen fertilizers led to a decrease in the content of leguminous species in herbage.

The yield of dry mass of single-species crops of festulolium provided the lowest yield among the studied stands both without nitrogen and with the introduction of N60. (table 3) The increase in yield in binary mixtures is due to the fact that in grass mixtures plants more fully use environmental resources.
Table 2. The content of festulolium in the herbage of single-species crops and binary mixtures, %.

| Variant | 2015 | 2016 | 2017 |
|---------|------|------|------|
| 1. Festulolium | 90.9 | 90.7 | 96.6 | 83.4 | 78.7 | 75.6 | 78.2 | 60.0 | 57.8 |
| 2. Festulolium + meadow clover | 67.1 | 47.1 | 51.9 | 53.4 | 50.5 | 48.2 | 49.2 | 41.2 | 39.8 |
| 3. Festulolium + birdsfoot trefoil | 67.5 | 41.1 | 57.2 | 45.0 | 44.3 | 43.7 | 41.9 | 42.9 | 41.4 |
| 4. Festulolium + variegated alfalfa | 77.9 | 41.2 | 61.5 | 46.5 | 47.3 | 48.0 | 45.4 | 39.6 | 44.0 |
| 5. Festulolium + Swedish clover | 67.7 | 52.2 | 54.0 | 55.3 | 54.6 | 59.3 | 53.1 | 42.1 | 16.8 |

Application of nitrogen fertilizers

| Variant | 2015 | 2016 | 2017 |
|---------|------|------|------|
| 1. Festulolium | 94.6 | 97.4 | 94.7 | 81.0 | 74.2 | 70.8 | 83.6 | 81.1 | 78.2 |
| 2. Festulolium + meadow clover | 73.8 | 74.2 | 64.7 | 53.1 | 32.8 | 41.8 | 36.7 | 27.4 | 27.7 |
| 3. Festulolium + birdsfoot trefoil | 74.4 | 76.6 | 68.3 | 63.1 | 37.7 | 35.0 | 33.8 | 30.5 | 29.7 |
| 4. Festulolium + variegated alfalfa | 79.1 | 65.4 | 77.4 | 52.0 | 26.3 | 34.4 | 25.3 | 20.8 | 19.7 |
| 5. Festulolium + Swedish clover | 76.4 | 76.4 | 67.2 | 59.4 | 38.0 | 39.3 | 36.4 | 23.5 | 29.3 |

Table 3. Productivity of dry mass of single-species crops and binary herbage with the participation of festulolium, t/ha.

| Species | 2015 | 2016 | 2017 | On average for three years |
|---------|------|------|------|----------------------------|
| No nitrogen fertilizers | | | | |
| Festulolium | 6.6 | 9.2 | 6.7 | 7.5 |
| Festulolium + meadow clover | 12.5 | 12.1 | 13.0 | 12.5 |
| Festulolium + birdsfoot trefoil | 8.8 | 12.4 | 9.7 | 10.3 |
| Festulolium + variegated alfalfa | 8.7 | 9.8 | 9.8 | 9.4 |
| Festulolium + Swedish clover | 9.9 | 9.8 | 8.6 | 9.4 |

Application of nitrogen fertilizers

| Species | 2015 | 2016 | 2017 | On average for three years |
|---------|------|------|------|----------------------------|
| Festulolium | 13.5 | 7.2 | 8.7 | 9.8 |
| Festulolium + meadow clover | 14.8 | 12.9 | 13.7 | 13.8 |
| Festulolium + birdsfoot trefoil | 14.0 | 11.0 | 13.5 | 12.8 |
| Festulolium + variegated alfalfa | 13.9 | 10.6 | 12.7 | 12.4 |
| Festulolium + Swedish clover | 13.4 | 9.7 | 7.9 | 10.3 |
| HCP for factor A (composition at inoculation) | 1.2 | 0.9 | 1.3 | |
| HCP for factor B (nitrogen application) and the interaction of AB factors | 2.3 | 1.1 | 1.9 | |

The maximum yield of dry matter was obtained in two-component grass stands with meadow clover – 12.5 t/ha without N and 13.8 t/ha with N60 application. Binary mixtures with Swedish clover turned
out to be the least productive. The use of nitrogen fertilizers had a positive effect on the formation of herbage, which led to an increase in yield.

4. Conclusion
The maximum shoot-forming ability of festulolium was noted in the first year of using the herbage, further there is a significant decrease in the density of the shoots. The seeded species remained fairly high during the three years of research. The introduction of leguminous species into the grass mixture, as well as the introduction of nitrogen fertilizers in a dose of N60, made it possible to increase the yield of dry matter.

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