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FODDER PRODUCTION

Formation of the Productivity of a Legume–Grass Mixture under Conditions of Agrolandscapes in the Central Region of the Non-Chernozem Zone of the Russian Federation

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Abstract—The landscape approach to developing perennial grass cultivation practices made it possible to reveal ecologically homogeneous sections and to create the basis for organizing sustainable fodder production under the complex landscape conditions of the region. The adaptation characteristics of perennial grasses and their productivity are different in agromicrolandscapes characterized by the same geochemical association of relief features but on different hill slopes (southern and northern).

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The importance of perennial legume–grass mixtures in the Non-Chernozem Zone as the main source for increasing the full energy and protein value of fodder, preserving and increasing soil fertility, providing stability of agroecosystems, etc., is known. In the Tver oblast the productivity of perennial grasses varies markedly depending on landscape conditions. The recommendations on their cultivation developed for this region are in need of adaptation to the diverse soil and climate conditions. The purpose of our work was to study the characteristics of development and formation of the yield of a five-component legume–grass mixture depending on habitat conditions.

METHODS

The investigations were carried out at the permanent field station of the All-Russian Research Institute for Agricultural Use of Ameliorated Lands (VNIIMZ) with a total area of 50 ha, which is located 4 km southeast of Tver city within the limits of a medium-high terminal moraine hill of Moskovian age with a relative height of 15 m [1]. Plantings of the crops at the station are arranged as continuous bands intersecting all landscape positions of the terminal moraine hill. The effect of agroecological factors on the formation of productivity of field crops under various landscape and ameliorative conditions were studied in a crop rotation expanded in time and space. The rotation established on two bands (transects) is a typical crop rotation with a set of the main crops grown in the Tver oblast.

The reserve fields (in the form of a transect) are presented by a five-component legume–grass mixture and Caucasian goat's rue. The transects consist of parallel bands 7.2 m wide (for each crop) and 1400 m long. Tillage is of the same type along the entire band occupied by some crop, which allows the most accurate study of the adaptive reactions of plants to landscape conditions. The area under each crop on one transect is 1 ha. The effect of agrolandscape conditions was studied on a five-component legume–grass mixture, which consists of alfalfa hybrid Vega, red clover VIK-7, timothy VIK-9, meadow fescue VIK-5, and perennial ryegrass VIK-6.

Productivity formation was investigated within various geochemical agromicrolandscapes (AMLs) on the top of the hill and slopes of southern and northern aspect at permanent points spaced 40 m apart. The calculation area of the plot was 84 m^2, replication was threefold. The AMLs were variants in the experiment: transitional accumulative (TAs), transitional (Ts), and eluvial accumulative (EAs) of the southern slope; eluvial, hill top (E), transitional eluvial accumulative (Tn), and transitional accumulative (TAn) of the northern slope. A detailed description of their agroecological characteristics is given in the literature [1, 2].

The soils within the entire agrolandscape of the terminal moraine hill were characterized by a very low content of mineral nitrogen (5–7 mg/kg) and very high content of P_2O_5 (31.2–74.4 mg/100 g soil), the P_2O_5 content on the southern slope being 1.5–2 times higher than on the northern. The soil K_2O content was high only on the EAs AML (22.2 mg/100 g soil), in most other AMLs it was increased (15.4–19.5 mg/100 g), and on TAn it was low (9 mg/100 g soil).

Observations of the onset of phenological phases, dynamics of phytomass increment, formation of yield components of the legume–grass mixture, and change in the agrochemical and agrophysical properties of the soil were carried out.

Table 1. Dry weight productivity (centners/ha) of legume–grass mixture

Variant	1998	1999	2000	2001	2002	Average
TAs	52.5	52.0	54.6	72.7	52.7	56.9
Ts	54.9	51.6	53.1	68.6	62.5	58.2
EAs	70.6	49.1	66.9	69.4	72.2	65.6
E	66.6	48.1	62.4	69.1	68.6	63.0
EAn	77.1	51.2	70.9	68.2	79.9	69.5
Tn	74.3	52.9	69.7	68.7	65.9	66.3
TAn	80.8	56.6	74.8	71.2	83.1	73.3
$LSD_{0.5}$	3.1	4.9	3.0	2.9	3.1	1.9

RESULTS AND DISCUSSION

Productivity of perennial grasses during five years varied depending on the habitat (Table 1). In the first year the yield of the legume–grass mixture on the northern slope was substantially higher than on the southern. In the following year it didn't differ significantly on the hill top and northern and southern slopes.

In the last year of the investigations, when mainly hybrid alfalfa and timothy remained intact in the grass stand, dry matter was obtained most of all on the northern slope, especially on TAn. Sixth-year alfalfa develops a vigorous root system penetrating into deep horizons; therefore, the legume–grass mixture even under conditions of dry 2002 formed a good yield. On average for all years, it was most productive on agromicrolandscapes of the northern slope and less so on the hill top. The five-year investigations permit concluding the most active growth of perennial grasses on slopes of northern aspect and in low sections of the terminal-moraine hill agrolandscape.

A regression analysis of the data on the effect of various agroecological factors on production of the legume–grass mixture showed that this dependence is described by the following equations:

$$Y = -0.14X_1 - 1.5X_2 + 0.5X_3 - 0.74X_4 + 2.2X_5 + 1.02X_6 - 0.14X_7 - 0.13X_8 + 11.0X_9 - 0.1X_{10} - 0.08X_{11} + 0.15X_{12} - 0.16X_{13} - 0.08X_{14} - 0.25X_{15} - 0.04X_{16},$$

where Y is the fresh weight yield of the first cutting, centners/ha; X_1 is relative height; X_2 is depth of snow; X_3 is water equivalent in snow; X_4–X_7 are respectively the density, unit weight, porosity, moisture content of soil; X_8 is humus supply; X_9 is humus content; X_{10} is phosphorus content; X_{11} is potassium content; X_{12} is pH_{KCl}; X_{13} is hydrolytic acidity; X_{14} is solar radiation; X_{15} is cumulative effective temperatures; X_{16} is % decomposition of linen.

$$Y = -0.08X_1 - 0.37X_2 - 0.41X_4 + 2.01X_5 + 0.2X_7 - 0.06X_8 + 0.08X_9 - 0.04X_{10} - 0.07X_{11} - 0.06X_{13} - 26.93,$$

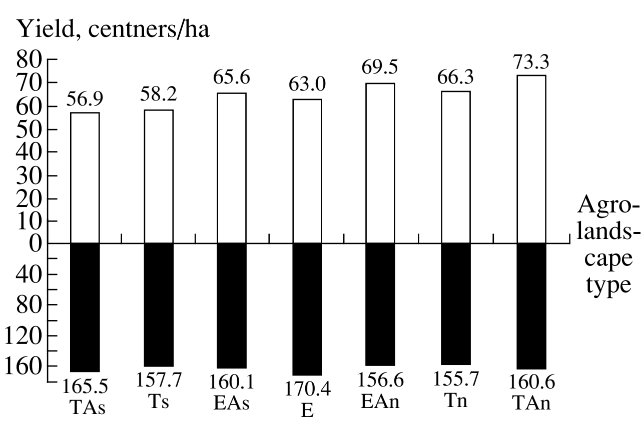
where Y is the fresh weight yield of the second cutting, centners/ha; X_1–X_{13} are parameters of the agrolandscape factors.

The weight of the first cutting of the legume–grass mixture depended mainly on the depth of the snow and its water equivalent. An increase of the water equivalent has a favorable effect on grass yield, since it promotes activation of physiological processes in the first growth phases.

The values of the absolutely dry weight of crop residues of the legume–grass mixture were 5–9 centners/ha depending on the agromicrolandscape. The maximum weight was noted on the TAn agromicrolandscape. The weight of roots in the 0–30-cm soil layer varied depending on the habitat and on average during 1998–2002 was 158.7–166.5 centners/ha on the southern slope and 155.7–160.5 on the northern; it was maximum, 170 centners/ha, on the hill top.

Plant residues of the legume–grass mixture, plowed under after the first growth year, left in the soil depending on the habitat: nitrogen 80–93.2 kg/ha, phosphorus 23.0–27.2 kg/ha, and potassium 78.5 kg/ha. Middle-aged stands were characterized by a higher content of these elements in the root mass than young ones. The nitrogen content in root residues of plants growing on the TAn agromicrolandscape was higher than in other habitats. The sixth-year growth mixture left up to 202–225 kg/ha nitrogen due to the large root mass. It was greater under this stand in the TA agromicrolandscape of both slopes.

An integral index objectively reflecting plant growth and development is the ratio of its aboveground and root mass (figure). The optimal ratio of above- and underground mass of the legume–grass mixture developed in the TAn agromicrolandscape and was 1 : 2.2, which provided a sufficient saleable product yield, the minimum value of which was noted on the transitional agrolandscapes.



Ratio of aboveground (upper columns) and root (lower) masses of legume–grass mixture on average during five years.

Table 2. Botanical composition of legume-grass mixture, % absolutely dry weight

Variant	Hybrid alfalfa		Red clover	Timothy		Meadow fescue		Perennial ryegrass	
	1998	2002	1998	1998	2002	1998	2002	1998	2002
TAs	27.1	36.3	15.4	42.3	48.1	6.3	8.2	2.9	4.2
Ts	23.4	35.5	16.1	50.1	47.7	6.1	8.2	2.3	4.6
EAs	26.9	37.1	13.8	46.3	48.9	6.9	8.0	2.7	4.0
E	24.9	36.1	15.1	45.3	47.2	7.4	8.1	2.9	4.1
EAn	22.3	38.9	16.2	46.5	48.7	7.6	8.1	2.8	2.3
Tn	29.8	36.1	15.4	45.0	47.5	6.4	7.9	2.0	3.6
TAn	27.4	37.0	16.0	46.3	48.8	6.9	10.3	1.9	1.9

The botanical composition of the five component mixture was formed under the effect of many factors, mainly the conditions of the agromicrolandscape and growth year. In 1998 timothy and perennial ryegrass and, of the legume component, hybrid alfalfa predominated in the mixture. In the first growth year the botanical composition of the mixture changed little on the agromicrolandscapes (Table 2).

In 2002 the mixture contained more hybrid alfalfa on the EA and TAn AMLs. Accumulative processes (especially on the northern slope), just as in 1998, created the most favorable conditions for growth of this plant. Timothy predominated in the stand of the TA and EA agromicrolandscapes. The content of meadow fescue in the mixture on the TAn agromicrolandscape was slightly higher and the share of participation of perennial ryegrass was 1.3–2.5 times lower than in other AMLs. Mixtures in the transitional and eluvial AMLs were marked by the highest content of unsown grass species in 2002.

On average during the five years, the TAn agromicrolandscape was characterized by the maximum content of the legume component (33.3% alfalfa and 7% clover). There was more timothy in the composition of mixtures in Ts and TAn agromicrolandscapes (48.6–48.9%). The content of meadow fescue in various AMLs varied insignificantly. The participation of perennial ryegrass in the stand decreased in the AMLs of the northern slope, since it is less winter hardy. More forbs were contained in the stands of the E and EA agromicrolandscapes.

The content of crude protein in absolutely dry weight varied from 14 to 19%. The best fodder with respect to this index was obtained on second-year grasses. In 1999 red clover and hybrid alfalfa, which formed many radical leaves, had still not disappeared. There was less protein in the fresh mass of the legume–grass mixture growing on the northern slope of the hill. The trend of the change in the crude cellulose content was opposite to the change in the crude protein content. The crude fat content in fodder from year to year was 2–4.5%. No regularity was noted in the change of content depending on habitat.

Growing the five-component legume–grass mixture for six years had a favorable effect on soil fertility. The content of mobile forms of phosphorus increased from 60 to 69 mg/100 g on agromicrolandscapes of the southern slope, from 30.1 to 44.4 mg/100 g on those of the northern slope, and from 28.9 to 29.4 mg/100 g soil on the top of the hill. The same trend was observed for mobile forms of potassium. The humus content increased by 0.2–0.4%.

The five-year investigations permit concluding a rather high stability of the studied grass species in various AMLs. At the same time, we can note a higher productivity of the five-component mixture on northern slopes as well as in depressions of the relief, where the optimal water, air, and nutritional regimes of soils develop.

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