

Features of crop formation and productivity of legume-festulolium grass mixtures in the Central region of the Non-Chernozem zone of Russia

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Abstract. The article presents the results of four years of research in a field experiment conducted on medium-loamy gray forest soil of the Kaluga region. The soil of the experiment was characterized by: humus content - 2.7%, pH – 5.9, gross nitrogen content - 0.12%, mobile phosphorus content - 135, exchangeable potassium - 100 mg/kg of soil. Objects of research: festulolium of the Fest and Allegro varieties, skip-row sown and in mixtures with legumes grasses - meadow clover of the Delets and Orlovsky varieties, alfalfa variable Sarga variety and Eastern galega Gale variety. Legumes-festulolium grass mixtures on average for three years formed the green mass and dry matter yield in the range of 34.5-43.5; 34.8-43.9 and 7.2-9.3; 7.2-9.4 t/ha, respectively, with skip-row and mixed sowing methods. The maximum productivity was obtained in a grass mixture of alfalfa of the hybrid Sarga variety with festulolium of the Allegro variety. The yield of exchange energy in legume-festulolium grass mixtures was in the range of 66.8-90.4 and 68.1-91.3 GJ/ha, respectively, with skip-row and mixed crops. The largest collection was provided by alfalfa-festulolium mixtures. Alfalfa grass mixtures of the Sarga variety with festulolium of the Fest and Allegro varieties provided the collection of crude protein 17.1-17.3 and 16.7-17.2 c/ha, respectively, with skip-row and mixed sowing methods. The collection of crude protein in clover- and galega-festulolium grass mixtures did not exceed 11.7 and 12.0 c/ha. The total energy costs and the energy efficiency coefficient according to the experimental variants were 17.2-17.7 GJ/ha and 3.8-5.1 for skip-row, 17.3-17.8 GJ/ha and 3.9-5.1 for mixed crops, respectively. Grass mixtures with the participation of alfalfa of the Sarga variety and festulolium of the Fest and Allegro varieties had the highest total energy costs and the maximum energy efficiency coefficient.

1 Introduction

The lack of feed and its imbalance in protein can be compensated by expanding the acreage under legumes and legume-cereal grass mixtures, characterized by increased collection of

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feed mass and the quality of the feed produced from it. Studies conducted in the Central Non-Chernozem zone proved that perennial legume-cereal grass mixtures had a lower cost of cultivation, and the energy efficiency of feed protein production from perennial grasses is 2-3 times higher than from winter grasses and 4-6 times higher than from spring legume-cereal mixtures [1-6].

Another weighty argument in favor of the use of perennial grasses are the reduced volumes of organic fertilizers in the country and the high cost of mineral fertilizers, while the problems of preserving and restoring soil fertility are increasing. Perennial grasses, especially legumes and legume-cereal grass mixtures, are currently almost the only available means of increasing the yield of field crops, protecting the soil from erosion and degradation, creating conditions for the formation of sustainable ecosystems.

Giving preference to grass mixtures, researchers note the stability of their yields, balance in basic nutrition elements and a positive effect on soil fertility at low feed production costs [7-9].

The efficiency of the use of herbal mixtures is largely determined by the biological characteristics of their components. Increasingly, the mixture began to include festulolium (*Festulolium F.Ascherset Graebn.*) - a hybrid of meadow fescue and Australian rye-grass, in terms of yield and feed quality close to Australian rye-grass, in terms of longevity – to meadow fescue. It is the most winter-hardy and less prone to the formation of inflorescences in subsequent mowing [10]. New varieties of festulolium - Fest and Allegro are interest as a cereal component, which have proven themselves to be highly productive and high in sugar content.

As legume components of grass mixtures for haymaking purposes in the Non-Chernozem zone, meadow clover is most often used, forming a significant feed mass in the first two years of use, variegated alfalfa, characterized by an increased protein content and insufficient amount of sugars, and Eastern galega, slowly developing in the first years of use.

The purpose of the research in the field experiment was to study the features of crop formation and productivity of legume-festulolium grass mixtures in the conditions of the Central Non-Chernozem zone with skip-row and mixed crops.

2 Materials and Methods

The field experiment was conducted at the Kaluga Research Institute of Agriculture experimental field in 2015-2018. The soil of the experiment is gray forest medium loamy. Humus content is 2.7%, pH - 5.9, gross nitrogen content - 0.12%, mobile phosphorus content - 135, exchangeable potassium - 100 mg/kg of soil.

The registration plot area is 20 m². The repetition in the experiment is threefold, the placement of plots is systematic. Sowing was carried out on May 25, 2015 with a SN seeder – 16P. The predecessor in the experiment is oats. The components in the grass mixtures were sown at the rate of 50% of their seeding rate in pure form.

The objects of research were two festulolium varieties: Fest and Allegro, sown in skip-row and in mixtures with legume components of different life spans - meadow clover of the Delets and Orlovsky varieties, variegated alfalfa variety Sarga and Eastern galega variety Gale.

The years of research, varying in meteorological conditions, made it possible to comprehensively study the features of crop formation of the studied species of perennial grasses and grass mixtures. The growing season of 2015 was close to the average annual norm in terms of air temperature, but was characterized by an uneven distribution of precipitation. The period of 2016 was excessively humid and warm, which allowed to obtain significant yields of fodder mass already in the second year of grass life. The

growing season of 2017 was close to the average annual values in terms of temperature and precipitation, but their distribution was uneven during the growing season. In the period of 2018, there was an alternation of hot and cool weather, with precipitation distribution close to the long-term average values.

The experiment trial, observations, records, and analyses were carried out according to generally accepted methods [11, 12].

3 Results and Discussion

The green mass yield and the collection of dry matter depended on the composition of the studied perennial grass mixtures, on the nature of meteorological conditions during the years of research and to a lesser extent on sowing method (Table 1).

Most of the studied variants of legume-festulium grass mixtures, the largest yield of green mass was formed in 2017 for the second year of herbage use with skip-row and mixed crops of components. The best yield indicators for skip-row sowing were obtained in mixtures of festulium of the Fest and Allegro varieties with alfalfa of the Sarga variety - 46.5 t/ha, respectively. With mixed sowing, these grass mixtures were superior to other options and formed the yield of green mass of 48.3 and 47.3 t/ha, respectively.

On average, for 3 years, these grass mixtures exceeded the yield of other crops in terms of green mass, I form a yield depending on festulium variety in the range of 43 - 43.5 t/ha. It should be noted that in the composition of alfalfa-festulium grass mixtures, the proportion of alfalfa was 55-56%, while the studied clover-festulium mixtures had a share of legumes 45-49%, and galega-festulium mixtures - 41-43%, depending on sowing method.

Table 1. Yield of green mass of legume-festulium grass mixtures with different sowing methods, t/ha.

N o.	Option	Yield of green mass total for 2 mowing							
		2016		2017		2018		Average for 3 years	
		total	% legumes	total	% legumes	total	% legumes	total	% legumes
1	2	3	4	5	6	7	8	9	10
Skip-row sowing									
1	Festulium Fest + Delets clover	42.2	57	43.1	44	30.3	43	38.5	48
2	Festulium Fest + Orlovsky clover	41.5	60	37.8	43	27.8	35	35.7	46
3	Festulium Fest + Sarga alfalfa	39.7	58	46.5	52	42.9	57	43.0	56
4	Festulium Fest + Gale galega	24.0	26	39.2	43	43.3	61	35.5	43

5	Festulolium Allegro + Delets clover	40.4	55	44.2	45	35.8	46	40.1	49
6	Festulolium Allegro + Orlovsky clover	42.9	57	41.2	43	29.5	36	37.9	45
7	Festulolium Allegro + Sarga alfalfa	39.4	55	46.5	53	44.6	61	43.5	56
8	Festulolium Allegro + Gale galega	22.7	30	37.1	40	43.7	59	34.5	43
LSD 05		1.50		2.21		1.53			
Mixed sowing									
9	Festulolium Fest + Delets clover	39.3	59	37.9	41	27.2	33	34.8	44
10	Festulolium Fest + Orlovsky clover	39.8	56	42.9	48	32.9	44	38.5	49
11	Festulolium Fest + Sarga alfalfa	38.4	57	48.3	51	44.4	57	43.7	55
12	Festulolium Fest + Gale galega	23.4	29	37.6	40	44.2	59	35.1	43
13	Festulolium Allegro + Delets clover	39.7	58	42.1	45	30.8	38	37.5	47
14	Festulolium Allegro + Orlovsky clover	37.7	56	44.6	45	35.1	46	39.1	49
15	Festulolium Allegro + Sarga alfalfa	36.8	55	47.3	53	47.5	58	43.9	55
16	Festulolium Allegro + Gale galega	21.1	23	41.0	42	45.2	59	35.8	41
LSD 05		1.14		1.56		1.13			

The collection of dry matter in the studied herb mixtures differed by the herbage years of life, it was maximum in the third year of the life of the herbs in all experiment options (Table 2). Clover- and alfalfa-festulolium grass mixtures increased the collection of dry matter until the third year of life, reducing yields by the fourth year with both sowing methods.

The share of the legume component by the fourth year of the life of herbs in clover-festulolium grass mixtures, depending on the experiment option, decreased to 35% in clover of the Orlovsky variety and 46% in the Delets variety with skip-row sowing, to 33% in the Delets variety and 46% in the Orlovsky variety with mixed sowing. In alfalfa-festulolium mixtures, the proportion of the legume component in the fourth year of the life of grasses under the studied sowing methods exceeded the corresponding values of the third year of the life of herbage and amounted to 57-61%, depending on sowing method.

Galega-festulolium herb mixtures in most of the studied experiment options increased the collection of dry matter with an increase in the duration of use, which is explained by an increase in the proportion of slowly developing Eastern galega in the harvest by the fourth year of life.

On average, over 3 years, the highest yield of dry matter was obtained in alfalfa-festulolium mixtures - 9.2-9.3 t/ha with skip-row sowing of components and 9.3-9.4 t/ha with mixed sowing.

Table 2. Collection of dry matter of legume-festulolium mixtures with different methods of sowing, t/ha.

Option	Collection of dry matter total for 2 mowing			
	2016	2017	2018	average for 3 years
Skip-row sowing				
Festulolium Fest + Delets clover	7.7	8.5	6.1	7.4
Festulolium Fest + Orlovsky clover	8.1	8.2	5.6	7.3
Festulolium Fest + Sarga alfalfa	8.4	10.9	8.7	9.3
Festulolium Fest + Gale galega	4.7	9.3	9.2	7.8
Festulolium Allegro + Delets clover	7.4	9.2	7.2	7.9
Festulolium Allegro + Orlovsky clover	8.4	8.7	5.9	7.7
Festulolium Allegro + Sarga alfalfa	8.2	10.6	8.9	9.2
Festulolium Allegro + Gale galega	4.6	8.4	8.7	7.2
LSD 05	0.27	0.31	0.21	0.24
Mixed sowing				
Festulolium Fest + Delets clover	9.3	9.3	6.4	8.3
Festulolium Fest + Orlovsky clover	7.8	8.4	5.4	7.2
Festulolium Fest + Sarga alfalfa	8.0	11.5	8.8	9.4
Festulolium Fest + Gale galega	7.2	8.7	8.9	7.2
Festulolium Allegro + Delets clover	6.9	9.3	7.0	7.7
Festulolium Allegro + Orlovsky clover	7.8	8.8	6.1	7.6
Festulolium Allegro + Sarga alfalfa	7.7	10.8	9.4	9.3
Festulolium Allegro + Gale galega	4.3	9.3	9.0	7.6
LSD 05	0.25	0.30	0.23	0.24

In skip-row and mixed sowings of clover-festulolium and alfalfa-festulolium mixtures, the maximum accumulation of exchange energy was noted in the second year of herbage use, and galega-festulolium mixtures had the highest indicators of exchange energy in the third year of use (Table 3). The highest yield of exchange energy was observed in the herbaceous crops of the Sarga variety with festulolium of the Fest and Allegro varieties

with skip-row 105.3 and 103.7 GJ/ha and mixed sowings 110.5 and 105.1 GJ/ha, respectively.

On average, over 3 years, the yield of exchange energy in legume-festulolium grass mixtures was in the range of 66.8-90.4 and 68.1-91.3 GJ/ha, respectively, with skip-row and mixed sowings. The largest collection was provided by alfalfa-festulolium mixtures.

Table 3. The yield of exchange energy and crude protein in legume-festulolium grass mixtures with different sowing methods, in total for 2 mowing.

Option	Exchange energy, GJ/ha				Crude protein, c/ha			
	2016	2017	2018	average for 3 years	2016	2017	2018	average for 3 years
Skip-row sowing								
Festulolium Fest + Delets clover	75.0	81.3	58.4	71.2	12.8	13.1	9.2	11.7
Festulolium Fest + Orlovsky clover	80.2	77.4	51.6	69.7	13.1	12.3	7.8	11.1
Festulolium Fest + alfalfa Sarga	83.7	105.3	82.3	90.4	15.9	18.9	17.2	17.3
Festulolium Fest + galega Gale	40.4	73.3	87.6	66.8	6.6	14.2	15.1	12.0
Festulolium Allegro + Delets clover	71.8	88.4	69.1	76.4	11.3	14.4	10.6	12.1
Festulolium Allegro + Orlovsky clover	83.4	82.9	57.6	74.6	13.2	13.1	8.3	11.5
Festulolium Allegro + Sarga alfalfa	81.5	103.7	83.1	89.4	14.9	18.2	16.8	17.1
Festulolium Allegro + Gale galega	40.8	77.6	85.4	66.3	6.5	12.2	14.7	11.1
Mixed sowing								
Festulolium Fest + Delets clover	91.1	90.6	62.3	81.3	11.1	14.4	9.7	11.7
Festulolium Fest + Orlovsky clover	77.5	78.9	50.3	68.9	12.8	12.6	7.3	11.6
Festulolium Fest + Sarga alfalfa	78.3	110.5	85.1	91.3	14.3	19.5	17.8	17.2
Festulolium Fest + Gale galega	39.6	81.2	83.4	68.1	6.5	13.3	14.7	11.5
Festulolium Allegro + Delets clover	68.4	89.1	68.4	75.3	11.8	14.5	10.1	12.1
Festulolium Allegro + Orlovsky clover	77.1	83.5	57.6	72.7	12.4	13.3	8.7	11.4
Festulolium Allegro + Sarga alfalfa	76.3	105.1	88.6	90.0	14.0	17.8	17.6	16.5
Festulolium Allegro + Gale galega	37.5	87.7	85.6	70.3	6.3	14.1	14.8	11.7

The collection of raw protein in legume-cereal grass mixtures is largely determined by the type of legume component and the share of its participation in the herbage. In the conditions of experiment, it differed by the years of use of herbage, depended on the composition of the mixtures and to a lesser extent on the method of sowing the components in the mixture.

In clover-festulolium mixtures, the collection of crude protein was determined by the varietal characteristics of the clovers used. The greatest collection of crude protein was obtained in a mixture of festulolium with meadow clover of the Delets variety for the second year of use of the herbage with both sowing methods, and in a mixture of festulolium with clover of the Orlovsky variety - for the first year of use. This is probably due to the high proportion of the participation of the meadow clover of the Delets variety in the herbage of the second year of life.

In alfalfa-festulolium mixtures, the largest collection of crude protein was obtained in the second year of use with both sowing methods.

The Eastern galega, belonging to a slowly developing species, in the studied grass mixtures, the maximum protein collection was given in the third year of herbage use.

On average, for 3 years, the largest collection of crude protein was obtained in mixtures of the studied varieties of festulolium with alfalfa of the Sarga variety 17.1-17.3 c/ha with skip-row and 16.7-17.2 c/ha with mixed sowing methods. This can be explained by the maximum share of alfalfa in the harvest - 55-56% and the highest yield of these grass mixtures.

In clover-festulolium mixtures, the collection of crude protein was determined by the varietal characteristics of the clovers used. The greatest collection of crude protein was obtained in a mixture of meadow clover of the Delets variety with festulolium for the second year of herbage use with both sowing methods, and in a mixture of clover of the variety Orlovsky with festulolium - for the first year of use. This is probably due to the high proportion of the participation of the meadow clover of the Delets variety in the herbage of the second year of life.

The Eastern galega, increasing the share of its participation in the total harvest of the grass mixture from the first to the third year of use, contributed to an increase in the collection of raw protein, nevertheless, on average for 3 years of field research galega-festulolium mixtures had the lowest collections of raw protein.

The demand for legume-cereal grass mixtures by production is determined by the economic and energy efficiency of their cultivation. Under the field experiment conditions, the energy efficiency of the studied methods of sowing legume-festulolium grass mixtures was similar in most indicators (Table 4). The total energy costs and the energy efficiency coefficient according to the experimental options differed, respectively, in the range of 17.2-17.7 GJ/ha and 3.8-5.1 for skip-row and 17.3-17.8 GJ/ha and 3.9-5.1 for mixed sowings.

Table 4. Energy efficiency of cultivation of legume-festulolium grass mixtures with different sowing methods, average for 3 years.

Option	Total energy costs, GJ/ha	Energy efficiency coefficient	Crude protein yield, c/ha	Energy costs for the production of 1 c of crude protein, GJ
Skip-row sowing				
Festulolium Fest + clover Delets	17.4	4.1	11.7	1.49
Festulolium Fest + clover Orlovsky	17.3	4.0	11.1	1.56
Festulolium Fest + alfalfa Sarga	17.8	5.1	17.3	1.03
Festulolium Fest + galega Gale	17.2	3.9	12.0	1.43

Festulolium Allegro + clover Delets	17.4	4.4	12.1	1.44
Festulolium Allegro + clover Orlovsky	17.4	4.3	11.5	1.51
Festulolium Allegro + alfalfa Sarga	17.7	5.1	17.1	1.04
Festulolium Allegro + galega Gale	17.2	3.8	11.1	1.55
Mixed sowing				
Festulolium Fest + clover Delets	17.5	4.6	11.7	1.50
Festulolium Fest + clover Orlovsky	17.3	4.0	11.6	1.49
Festulolium Fest + alfalfa Sarga	17.8	5.1	17.2	1.03
Festulolium Fest + galega Gale	17.3	3.9	11.5	1.50
Festulolium Allegro + clover Delets	17.4	4.3	12.1	1.44
Festulolium Allegro + clover Orlovsky	17.4	4.2	11.4	1.53
Festulolium Allegro + alfalfa Sarga	17.7	5.1	16.7	1.06
Festulolium Allegro + galega Gale	17.4	4.0	11.7	1.49

Grass mixtures with the participation of alfalfa of the Sarga variety and festulolium of the Fest and Allegro varieties had the highest total energy costs and the maximum energy efficiency coefficient, these types of grass mixtures also had the lowest energy costs for the production of 1 c of crude protein.

4 Conclusion

One of the promising sources of feed raw materials are perennial legume-cereal grass mixtures, with the participation of festulolium. As a result of four years of research in field experiment, it was proved that in the conditions of the Central Non-Chernozem zone on gray forest medium loamy soil, perennial legume-festulolium grass mixtures on average for three years formed the yield of green mass in the range of 34.5-43.5 and 34.8-43.9 t/ha, respectively, with skip-row and mixed sowing methods. The harvesting of dry matter reached 7.2-9.3 and 7.2-9.4 t/ha, respectively, with skip-row and mixed crops. The maximum productivity was obtained in the grass mixture of alfalfa of the hybrid variety Sarga with festulolium of the Allegro variety, while the share of alfalfa in the harvest was 55-56%, depending on the experiment option and the sowing method. The yield of exchange energy in legume-festulolium grass mixtures was in the range of 66.8-90.4 and 68.1-91.3 GJ/ha, respectively, with skip-row and mixed sowings. The largest collection was provided by alfalfa-festulolium mixtures.

Alfalfa herb mixtures of the Sarga variety with festulolium of the Fest and Allegro varieties provided the collection of crude protein 17.1-17.3 and 16.7-17.2 c/ha, respectively, with skip-row and mixed sowing methods. The collection of crude protein in clover- and galega-festulolium grass mixtures did not exceed 11.7 and 12.0 c/ha.

The energy efficiency of legume-festulolium grass mixtures with skip-row and mixed sowing methods was close in most indicators. The total energy costs and the energy efficiency coefficient according to the experiment options differed in the range of 17.2-17.7

GJ/ha and 3.8-5.1 for skip-row and 17.3-17.8 GJ/ha and 3.9-5.1 for mixed sowings, respectively.

Grass mixtures with the participation of alfalfa of the Sarga variety and festulolium of the Fest and Allegro varieties had the highest total energy costs and the maximum energy efficiency coefficient, these types of grass mixtures also had the lowest energy costs for the production of 1 c of crude protein.

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