Sys Rev Pharm 2021;12(3):460-469
A multifaceted review journal in the field of pharmacy

Features Of The Formation Of Single-Species And Heterogeneous Agrocenoses Of Medick And Perennial Meadow-Grasses In Field Forage Production

ABSTRACT

The relevance of research is due to the need to improve individual elements of agrotechnology for medick and perennial meadow-grasses cultivation depending on the background of mineral nutrition, and for the creation of highly productive herbage in the gray forest soils of the southwestern part of the Central region of the Russian Federation. Perennial legumes in single-species and heterogeneous crops are the main components in solving the problem of vegetable protein in the production of the highest quality feed. The methodology of field experiments is based on the principle of intensification and biologization of agriculture. The research aims at developing elements of agricultural technologies for the cultivation of perennial grasses in single-species and heterogeneous crops and at improving the biochemical composition of forages, depending on both the species composition of the grass mixture and the effect of the background of mineral fertilizers on the yield in single-species and heterogeneous field agrocenoses. The research methods were field, laboratory, and statistical. Field studies were carried out on the experimental field of Bryansk State Agrarian University using a modern assortment of medick and perennial meadow-grasses on various backgrounds of mineral fertilizers. In the grass mixtures, the legume component varied from 40 to 50%. Sowing was carried out under the cover of one-year-old Westerwolds ryegrass (Lolium multiflorum Lam. var. westerwoldicum Wittm). Medick (Medicago varia Mart.) was used as the legume component. Meadow-grasses are represented by timothy (Phleum pratense L.), meadow fescue (Festuca pratensis Huds.), cat grass (Dactylis glomerata L.), and awnless brome (Bromus inermis). The formation of the yield of green mass and dry matter of medick and perennial meadow-grasses mixtures is justified by the background of mineral nutrition and the species composition of cultivated grass mixtures. On average, over the years of field experiments, the maximum yield (45.32 t/ha) of green mass and of dry matter (11.33 t/ha) was obtained in the variant of medick-fescue grass mixture against the background of prolonged action of Borofoska in combination with annual nitrogen fertilization at the dose N30. Under the influence of mineral fertilizers, an improvement in the biochemical composition of dry matter of heterogeneous crops of legume-perennial meadow-grasses was noted. The highest indices of nutrients were found in the forage mass of the medick-timothy grass mixture.

Keywords: biochemical composition, medick, mixed heterogeneous agrocenoses, mineral fertilizers, productivity.

INTRODUCTION

The sustainable development of animal husbandry and feed production can now be characterized by an integrated approach to the introduction of elements of intensive agricultural technologies, the main direction of which should be to increase the natural resource potential of agrophytocenoses and, as a result, the lack of the required amount of energy-saturated feed balanced in terms of the carbohydrate-protein complex. Often, the structure of perennial grasses is dominated by species of meadow-grasses. Consistently high yields of perennial grasses can be achieved through careful selection of the species composition and optimal stalk density. If modern assortment of medick and perennial meadow-grasses in single and heterogeneous crops are used, perennial legumes become the key components in solving the protein deficiency problem in energy-rich feed production. It is known that heterogeneous crops of perennial legumes and grasses have a clear advantage in productivity over single-species agrophytocenoses as they use nutrients from soil and fertilizers, and moisture much more efficiently (Belchenko et al., 2016a, 2020; Belyak et al., 2016; Dyachenko et al., 2015b, 2016, 2020; Dospekhov, 1985; Dyachenko & Belchenko, 2020).

Certain authors state that the use of phosphorus fertilizers is effective in reducing the intake of radionuclides in the harvest of commercial crop production. At the same time, achieving optimal fertility parameters of this type gives the highest yield of cultivated crops, which leads to a decrease in the concentration of radiocaesium in the products due to the effect of biological dilution. Increased doses of potash fertilizers with the simultaneous introduction of lime materials give the greatest effect, thereby reducing the concentration of cesium-137 in crop production 2 to 20 times (Pakshina et al., 2017a, 2017b; Belous et al., 2010, 2012, 2016, 2017, 2019; Belchenko et al., 2016b).

According to scientists of the All-Russian Research Institute of Feed Production and Agroecology named after V.R. Williams, a significant increase in sowing perennial leguminous grasses in single-species and heterogeneous crops up to 75-80% of the total area provides an increase in the yield of feed mass to 17-18 t/ha while reducing the cost of feed 1.5-1.6 times and solves the problem of the production of high-protein green and roughage. In addition, heterogeneous crops are a reserve for biological crop production due to the increasing efficiency of using natural factors: insulation, mineral food elements and moisture against the background of agrotechnical measures. Notably, there is a practical possibility of changing the nature of the mineral nutrition of plants and actively influencing the quality parameters from perennial herbage (Ershov et al., 2017; Isakov & Lukashov, 2011; Gamko et al., 2016; Dyachenko et al., 2015a; Shapovalov et al., 2016; Esedulaev & Shmeleva, 2014, 2017; Anderson & Roed, 1994; Zhy et al., 2000; Lassey, 1979; Rafferty & Coigan, 1994; Smolders, 1995).

A highly effective method for reducing the intake of radiocaesium in agricultural plants is the use of mineral fertilizers, with potash fertilizers playing a leading role. The recommended method is the liming of acidic soils, which leads to a decrease in the acidity of the soil solution and to an increase in the saturation of soils with bases, which helps reduce the degree of mobility of radionuclides in the soil and limits their availability to plants.

In this regard, cultivation of perennial leguminous grasses in single-species and heterogeneous crops largely solves the problem of producing high-protein energy-rich feed with fairly significant savings in nitrogen fertilizers. The present research aimed at developing elements of agricultural technologies for perennial grasses cultivation in single-species and heterogeneous crops, and at improving the biochemical composition of forages, depending on both the species composition of the grass mixture and the influence of the mineral fertilizers background on the yield in single-species and heterogeneous field agrocenoses of medick and perennial meadow-grasses grown for green forage and hay. The methodological basis of the field experiment was the principle of intensification and biologization of agriculture.

MATERIALS AND METHODS

The studies were carried out in 2015-2019 at the experimental field of Bryansk State Agrarian University. The soils of the field experiment are gray forest, light loamy, medium-cultivated, formed on carbonate loess-like loams. The thickness of the humus horizon is 30-60 cm, the presence of humus varies from 2.6 to 3.2%. The reaction of the soil solution is weakly acidic, the pH of the salt extract is 5.2-5.6, the content of mobile phosphorus is 250-350 mg and of exchangeable potassium 130-150 mg per 1 kg of soil (according to Kirsanov). The object of research is perennial grasses from medick-meadow-grass composition. Bryansk Oblast is geographically located in the southwestern part of the Central region of Russia. The climate of the region is moderately continental. During the year, precipitation ranges from 560 to 600 mm; more than half of it falls during the growing season of plants. The hydrothermal coefficient averages 1.4 for the entire growing season.Grass mixtures were in the following proportions: 45% legume component and 55% cereal component. Sowing was carried out under the cover of one-year-old Westerwolds ryegrass (L. *westerwoldicum* Wittm.), diploid Izorsky variety. Medick (*M. varia* Mart.) Lugovaya-67 cultivar was used as the legume component. The meadow-grass component is represented by timothy (*P. pratense* L.) VIK-9 cultivar, meadow fescue (*F. pratensis* Huds.) Krasnopoymskaya 92 cultivar, cat grass (*D. glomerata* L.) VIK-61 cultivar, and awnless brome (*Bromus inermis*) SIBNISHOZ-99 variety.Perennial grasses were sown in the 3rd decade of April at the seeding rate of 15-16 kg/ha using a SN-16 seeder was used. The (sowing) plot area was 30м^2, multiple repetition, systematic placement of plots. When cultivating perennial grasses, the generally accepted agricultural technique was used for the zone. The experience was two-factor: mineral fertilizers background as Factor A and types of grass mixtures as Factor B.The study of productivity and biochemical composition of grass mixtures hay was carried out on the following backgrounds: without Borofoska (N_{30}); 272kg/ha of Borofoska ($P_{30}K_{35}+N_{30}$ background); $P_{60}K_{70}+N_{30}$ background; $P_{105}K_{120}+N_{30}$ background. Borofoska was applied once in early spring before the growing season of perennial grasses and at the same time added to the fertilizer - ammonium nitrate at the rate of 89 kg/ha (N_{30}).Crop accounting was continuous – plot by plot. The yield of hay was determined by drying the green mass from 1 m^2 air state to a constant weight. The studies were carried out in accordance with the Guidelines for conducting field experiments with feed crops (RAA, 1997). The results were processed by statistical analysis of variance according to B.A. Dospekhov (1985). Laboratory and analytical studies were carried out according to the methods generally accepted in the agrochemical service at the Center for Shared Use of Instrumental and Scientific Equipment of Bryansk State Agrarian University. In plants, the following was determined: dry matter (when converted to crude protein, the coefficient of 6.25 was used); crude fiber according to Geneberg and Shtoman in the modification of the All-Russian Research Institute of Horse Breeding; and crude fat according to Rudkovsky. Nitrogen-free extractives are calculated according to the formula: NFE = 100 – (moisture + CP + CFi + CA + CFa), where: CP is crude protein, CFi is crude fiber, CA is crude ash, and CFa is crude fat.The results of experimental studies were processed using variance and correlation analysis based on computer support (Excel 7.0, Statistic 7.0, NCSS-2000) (Dyachenko et al., 2015b).

RESULTS

The experiment revealed that using Borofoska in combination with ammonium nitrate significantly increased the yield of green mass of medick and meadow-grasses mixtures in comparison with the nitrogen background (control) (Table 1). Even a relatively small dose of Borofoska ($P_{30}K_{35}$ background) together with nitrogen fertilization in most cases provides a statistically significant increase in the yield of green mass of the 1st-cutting medick and meadow-grasses mixtures of the 3rd year of life. Higher doses of Borofoska ($P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds) together with ammonium nitrate allow achieving a significant increase in the green mass yield – 1.63 to 6.57 t/ha.

Table 1. Yield of medick and meadow-grasses mixtures of the 3rd year of life, t/ha of green mass (1st cutting), 2017

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	$P_{30}K_{35}$ + N_{30}	$P_{60}K_{70}$ + N_{30}	$P_{105}K_{120}$ + N_{30}
Medick + timothy	23.80	25.31	25.43	24.20
Medick + meadow fescue	19.21	21.90	23.29	22.82
Medick + cat grass	16.49	19.38	19.47	18.58
Medick + awnless brome	12.53	14.51	17.12	19.10
HCP_{05} for Factor A (mineral fertilizers background) – 1.62				
HCP_{05} for Factor B (grass mixture) – 1.62				

HCP_{05} for particular differences – 3.23

Experiment accuracy, % – 3.10

The medick + timothy mixture had the highest productivity in the 1st cutting; the green mass yield ranged from 23.8 to 25.43 t/ha, but the yield increase due to Borofoska and ammonium nitrate was within the experimental error. The rest of the mixtures were characterized by a comparatively lower green mass yield – 12.53 to 23.29 t/ha; however, their responsiveness to Borofoska was reliable. The effect of high doses of Borofoska ($P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds) was especially pronounced in the medick + awnless brome mixture, where the increase (compared with the control) was 36-52%. The responsiveness to Borofoska in medick + meadow fescue and medick + cat grass was significantly lower.The 2nd cutting also showed that Borofoska positively affected the feed mass yield, but its values were significantly lower than in the 1st cutting – 12 to 19 t/ha, depending on the composition of the grass mixture and the dose of mineral fertilizers (Table 2).

Table 2. Yield of medick and meadow-grasses mixtures of the 3rd year of life, t/ha of green mass (2nd cutting), 2017

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	$P_{30}K_{35}$ + N_{30}	$P_{60}K_{70}$ + N_{30}	$P_{105}K_{120}$ + N_{30}
Medick + timothy	11.87	14.30	16.68	15.32
Medick + meadow fescue	14.11	18.01	19.07	16.32
Medick + cat grass	12.04	12.81	13.00	14.66
Medick + awnless brome	12.59	13.18	13.72	15.41

HCP_{05} for Factor A (mineral fertilizers background) – 0.37

HCP_{05} for Factor B (grass mixture) – 0.37

HCP_{05} for particular differences – 0.74

Experiment accuracy, % – 2.1

Even the use of Borofoska at the rate of 272 kg/ha ($P_{30}K_{35}$ background) provided a statistically significant yield increase in the 2nd cutting. Considering that the effect of ammonium nitrate on the 2nd cutting (the counting was carried out at the end of July) was insignificant, and the increase in the yield of grass mixtures can be explained by the effect of Borofoska. Notably, there is a significant advantage in the yield of meadow fescue grass mixtures on all the fertilizer backgrounds.The prolonged influence of Borofoska was clearly manifested during the formation of the 3rd cutting of medick and meadow-grasses (Table 3).

Table 3. Yield of medick and meadow-grasses mixtures of the 3rd year of life, t/ha of green mass (3rd cutting)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	$P_{30}K_{35}$ + N_{30}	$P_{60}K_{70}$ + N_{30}	$P_{105}K_{120}$ + N_{30}
Medick + timothy	5.90	7.30	8.12	9.03
Medick + meadow fescue	5.41	6.29	7.03	8.04
Medick + cat grass	5.78	7.28	7.19	7.52
Medick + awnless brome	5.61	6.92	7.74	7.50

HCP_{05} for Factor A (mineral fertilizers background) – 0.38

HCP_{05} for Factor B (grass mixture) – 0.38

HCP_{05} for particular differences – 0.82

Experiment accuracy, % – 2.84

Thus, all the studied doses of Borofoska provided a statistically significant increase in the green mass yield in comparison with the unfertilized background – 1.31 to 3.13 t/ha. Notably, even at the dose of 272 kg/ha ($P_{30}K_{35}$ background) Borofoska has a significant effect on the green mass yield of the medick and meadow-grasses mixtures.

Table 4. Yield of medick and meadow-grasses mixtures of the 3rd year of life, t/ha of green mass (three cuttings total)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	$P_{30}K_{35}$ + N_{30}	$P_{60}K_{70}$ + N_{30}	$P_{105}K_{120}$ + N_{30}
Medick + timothy	41.57	46.91	50.23	48.55
Medick + meadow fescue	38.73	46.20	49.39	47.18
Medick + cat grass	34.31	39.47	39.66	40.76
Medick + awnless brome	30.73	34.61	38.58	42.01

HCP_{05} for Factor A (mineral fertilizers background) – 2.04
HCP_{05} for Factor B (grass mixture) – 2.04
HCP_{05} for particular differences – 4.69
Experiment accuracy, % – 2.91

DISCUSSION

In general, in the agroclimatic conditions of Bryansk Oblast, medick and meadow-grasses of the 3rd year of life allow obtaining a fairly high yield of feed mass on gray forest soil (Table 4, Figure 1). Thus, for the growing season of 2017 (for three cuttings total), depending on the composition of the grass mixture and the background of mineral nutrition, the yield ranged from 31 to 58 t/ha of green mass. The combined use of Borofoska and ammonium nitrate significantly increases the yield of medick and meadow-grasses mixtures already in the 1st year. Thus, even a small dose of Borofoska at the rate of 272 kg/ha ($P_{30}K_{35}$) together with ammonium nitrate (N_{30}) increases the green mass yield from 3.88 to 7.5 tons/ha for certain grass mixtures. Borofoska at 545 and 920 kg/ha ($P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds) together with ammonium nitrate gives an even more significant increase in yield – 8 to 11 t/ha.

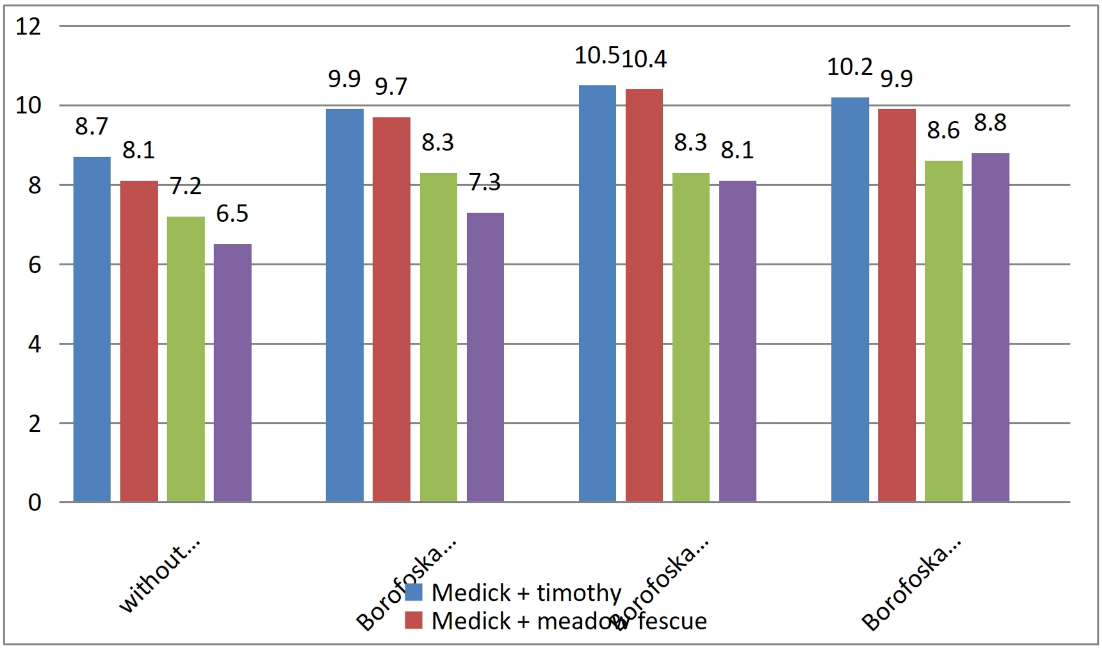

Figure 1. Dry matter yield of medick and meadow-grasses mixtures (3rd year of life), t/ha

Borofoska together with ammonium nitrate also significantly increased the dry matter yield to 10 or more t/ha for medick mixtures with timothy and meadow fescue, and up to 8 or more t/ha for grass mixtures of medick with cat grass. The dry matter yield of more than 8 t ha was provided by the medick and awnless brome mixture only against the background of Borofoska at 545 and 920 kg/ha. The introduction of Borofoska led to change in the botanical composition of herbage in the 3rd year of life. Fertilizers contributed to an increase in the share of medick by 3-12% with a proportional decrease in the share of meadow-grasses. In general, medick predominates in the structure of the grass mixtures yield, varying from 74.8-81.7% of the total mass, and the share of the meadow-grass component is 17.8 to 26.9%. The share of weed herbs is insignificant – 0.4 to 1.2%.

In 2018 (4th year of life), despite little snow, medick and meadow-grasses tolerated the winter relatively normally. In early spring, all the variants of the experiment were subjected to nitrogen fertilization with the calculated dose of N_{30} (about 90 kg/ha in physical terms), as well as early spring harrowing. The mode of using medick and meadow-grasses mixtures of the 4th year of life was transferred to a two-mowing scheme, and the whole complex of technological measures for hay preparation was carried out.Experiments revealed that the aftereffect of Borofoska in combination with ammonium nitrate (introduced in the year of research) significantly increased the green mass yield of medick and meadow-grasses mixtures compared with the background without Borofoska (Table 5). Even the aftereffect of Borofoska at 272 kg/ha in the 2nd year of application provides a statistically significant increase – 2.09 to 3.16 t/ha of green mass.

Table 5. Yield of medick and meadow-grasses mixtures of the 4th year of life, t/ha of green mass (1st cutting)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	aftereffect $P_{30}K_{35}$ + N_{30}	aftereffect $P_{60}K_{70}$ + N_{30}	aftereffect $P_{105}K_{120}$ + N_{30}
Medick + timothy	18.72	20.81	23.48	25.70
Medick + meadow fescue	20.54	23.19	25.10	24.85
Medick + cat grass	18.52	21.40	23.21	22.59

Medick + awnless brome	18.97	22.13	23.30	23.81

HCP_{05} for Factor A (mineral fertilizers background) – 1.58

HCP_{05} for Factor B (grass mixture) – 1.58

HCP_{05} for particular differences – 3.12

Experiment accuracy, % – 2.90

The highest Borofoska aftereffect was observed on the mixture of medick and awnless brome. Borofoska at 545 and 920 kg/ha ($P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds) together with ammonium nitrate gives an even more significant increase in yield – 4.76 to 6.98 t/ha. Notably, the highest increase in the yield of the 1st cut in this case was manifested in the mixture of medick and timothy (Table 6).

Accounting for the yield of the 2nd cut of medick and meadow-grasses of the 4th year of life clearly showed the effectiveness of the aftereffect of studied doses of Borofoska (Table 6).

Table 6. Yield of medick and meadow-grasses mixtures of the 4th year of life, t/ha of green mass (2nd cutting)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	aftereffect $P_{30}K_{35}$ + N_{30}	aftereffect $P_{60}K_{70}$ + N_{30}	aftereffect $P_{105}K_{120}$ + N_{30}
Medick + timothy	12.81	14.20	18.02	18.87
Medick + meadow fescue	15.18	19.67	20.34	22.03
Medick + cat grass	14.42	18.33	20.59	20.41
Medick + awnless brome	13.39	16.42	19.60	18.36

HCP_{05} for Factor A (mineral fertilizers background) – 0.51

HCP_{05} for Factor B (grass mixture) – 0.51

HCP_{05} for particular differences – 0.98

Experiment accuracy, % – 2.7

Thus, the aftereffect of Borofoska at 272 kg/ha provides a statistically significant increase in the green mass yield in comparison with the unfertilized background – 1.39 to 4.49 t/ha, depending on the grass mixture. The aftereffect of Borofoska at 545 and 920 kg/ha ($P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds) gives an even more significant increase in yield – 5.16 to 6.85 t/ha.

In general, evaluating the effectiveness of the 1st year aftereffect of Borofoska in combination with ammonium nitrate (N_{30}), we can state a statistically significant positive effect of this agricultural method on the total yield of feed mass for the growing season in 2018 (Table 7). The aftereffect of Borofoska at 272 kg/ha increased the yield in the context of the studied mixtures from 3.5 to 7.1 t/ha; and 545 and 920 kg/ha provide an even more significant increase – 10.5 to 13.0 t/ha of green mass. Notably, significant differences in the green mass yield for two cuttings from the aftereffect of $P_{60}K_{70}$ and $P_{105}K_{120}$ backgrounds are not observed for most of the studied mixtures. An exception here is medick+timothy mixture – its green mass yield is the highest against the $P_{105}K_{120}$ background (about 45 t/ha).

Table 7. Yield of medick and meadow-grasses mixtures of the 4th year of life, t/ha of green mass (two cuttings total)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	aftereffect $P_{30}K_{35}$+ N_{30}	aftereffect $P_{60}K_{70}$+ N_{30}	aftereffect $P_{105}K_{120}$+ N_{30}
Medick + timothy	31.53	35.01	41.50	44.57
Medick + meadow fescue	35.72	42.86	45.44	46.88
Medick + cat grass	32.94	39.73	43.80	43.00
Medick + awnless brome	32.36	38.55	42.90	42.17

HCP_{05} for Factor A (mineral fertilizers background) – 1.98

HCP_{05} for Factor B (grass mixture) – 1.98

HCP_{05} for particular differences – 4.57

Experiment accuracy, % – 3.01

During the 1st year, the aftereffect of Borofoska positively influenced the dry matter yield (Figure 2). Nitrogen fertilization without the aftereffect of Borofoska allows obtaining 8 to 9 t/ha of dry matter, and the aftereffect of Borofoska at 272 kg/ha together with ammonium nitrate provides an increase of 11% or more. The aftereffect of Borofoska at 545 and 920 kg/ha provides more than 10.5-11.0 t/ha of dry matter yield.

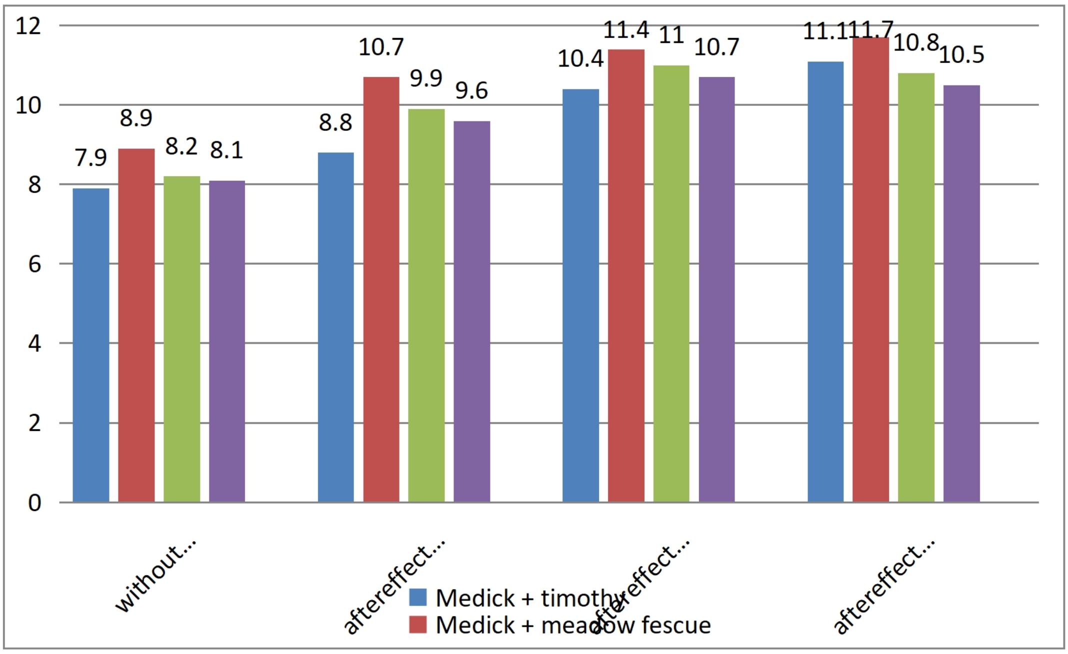

Figure 2. Dry matter yield of medick and meadow-grasses mixtures (4th year of life), t/ha

In 2019 (5th year of life), medick, awnless brome and cat grass wintered well, while meadow fescue and timothy were largely eliminated. In early spring, in all the variants of the experiment, nitrogen fertilization was carried out with the calculated dose of N_{30} (about 90 kg/ha of ammonium nitrate in physical terms), as well as early spring harrowing. Medick and meadow-grasses mixtures of the 5th year of life were used for making hay according to the two-mowing scheme.The 2nd year of the aftereffect of Borofoska at 545 and 920 kg/ha in combination with early spring nitrogen fertilization gives a statistically significant increase in the green mass yield of medick and meadow-grasses mixtures compared with the background without Borofoska (Table 8). The aftereffect of Borofoska at 272 kg/ha in the 3rd year of application, as a rule, does not provide a statistically significant increase.

Table 8. Yield of medick and meadow-grasses mixtures of the 5th year of life, t/ha of green mass (1st cutting)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	2nd year aftereffect $P_{30}K_{35}$ + N_{30}	2nd year aftereffect $P_{60}K_{70}$ + N_{30}	2nd year aftereffect $P_{105}K_{120}$ + N_{30}
Medick + timothy	15.34	16.79	21.05	23.65
Medick + meadow fescue	16.02	17.14	21.61	23.94
Medick + cat grass	18.29	19.81	22.97	24.30
Medick + awnless brome	19.15	20.23	23.12	25.07
HCP_{05} for Factor A (mineral fertilizers background) – 1.49				
HCP_{05} for Factor B (grass mixture) – 1.49				
HCP_{05} for particular differences – 2.97				
Experiment accuracy, % – 3.01				

The highest yield increase from the second year of the aftereffect of Borofoska at 545 and 920 kg/ha was observed on grass mixtures of medick with timothy and meadow fescue – 5.59 to 8.31 t/ha. The effect on grass mixtures of medick with cat grass and awnless brome was less significant, although these mixtures were generally 6-10% more productive, since by the 5th year of life timothy and fescue fell out of the herbage, and the yield of herbage was formed mainly due to medick.The yield of grass mixtures of the 5th year of life once again confirms the effectiveness of the prolonged action of high doses of Borofoska (Table 9). At the same time, the aftereffect of the minimum dose of Borofoska provides a slight yet reliable increase in yield.The aftereffect of Borofoska at 545 and 920 kg/ha can increase the yield of medick and meadow-grasses mixtures of the 5th year of life by 34-45% in comparison with the background without Borofoska. Notably, grass mixtures of medick with cat grass and awnless brome have a higher yield – about 20 t/ha.

Table 9. Yield of medick and meadow-grasses mixtures of the 5th year of life, t/ha of green mass (2nd cutting)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	aftereffect $P_{30}K_{35}$ + N_{30}	aftereffect $P_{60}K_{70}$ + N_{30}	aftereffect $P_{105}K_{120}$ + N_{30}
Medick + timothy	12.05	13.12	16.20	17.44

Medick + meadow fescue	12.37	13.23	17.03	17.95
Medick + cat grass	13.58	15.64	18.78	20.15
Medick + awnless brome	14.01	15.90	19.23	20.34

HCP_{05} for Factor A (mineral fertilizers background) – 0.93

HCP_{05} for Factor B (grass mixture) – 0.93

HCP_{05} for particular differences – 1.87

Experiment accuracy, % – 2.83

Evaluating the 2nd year aftereffect of Borofoska in combination with ammonium nitrate (N_{30}), we can state a significant positive effect of this agricultural method on the yield of feed mass for the growing season of 2019 (Table 10, Figure 3).

Table 10. Yield of medick and meadow-grasses mixtures of the 5th year of life, t/ha of green mass (two cuttings total)

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	2nd year aftereffect $P_{30}K_{35} + N_{30}$	2nd year aftereffect $P_{60}K_{70} + N_{30}$	2nd year aftereffect $P_{105}K_{120} + N_{30}$
Medick + timothy	27.39	29.91	37.25	41.09
Medick + meadow fescue	28.39	30.37	38.64	41.89
Medick + cat grass	31.87	35.45	41.75	44.45
Medick + awnless brome	33.16	36.13	42.35	45.41

HCP_{05} for Factor A (mineral fertilizers background) – 1.73

HCP_{05} for Factor B (grass mixture) – 1.73

HCP_{05} for particular differences – 4.40

Experiment accuracy, % – 2.85

The yield of the studied mixtures due to the 2nd year aftereffect of Borofoska at 272 kg/ha increased insignificantly from 2.0 to 3.6 t/ha, practically within the limits of statistical significance. The aftereffect of Borofoska at 545 and 920 kg/ha provided a more significant increase in yield – 9.2 to 13.7 t/ha of green mass. The highest yield (41-45 t/ha of green mass) was formed against the background of the aftereffect of Borofoska at 920 kg/ha.

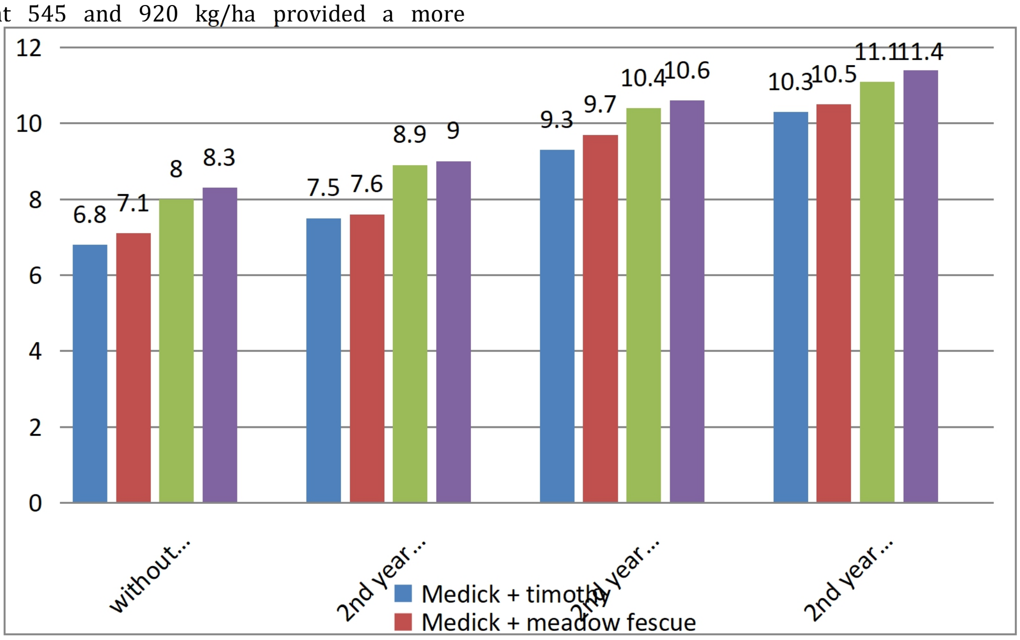

Figure 3. Dry matter yield of medick and meadow-grasses mixtures (5th year of life), t/ha

The 2nd year aftereffect of Borofoska positively influenced the dry matter yield of medick and meadow-grasses mixtures (Figure 3). One nitrogen fertilization allows obtaining 6.9 to 8.3 t/ha of dry matter; against the background of Borofoska at 272 kg/ha, the yield of dry matter was 7.5 to 9.0 t/ha. The aftereffect of Borofoska at 545 and 920 kg/ha, together with nitrogen fertilization, provided the dry matter yield of 9.3 to 11.4 t/ha.

In general, medick and meadow-grasses mixtures for 3-5 years of use (on average for 2017-2019) on gray forest soil (Bryansk Oblast), provide 40-45 t/ha of green mass and 10-11 t/ha of dry substances with a single application of Borofoska at 545 and 920 kg/ha, together with annual nitrogen fertilization (Table 11).

Table 11. Feed mass yield of medick and meadow-grasses mixtures for 3-5 years of use (on average for 2017-2019), t/ha

Factor B (grass mixture)	Factor A (mineral fertilizers background)			
	without Borofoska + N_{30}	$P_{30}K_{35} + N_{30}$	$P_{60}K_{70} + N_{30}$	$P_{105}K_{120} + N_{30}$
Medick + timothy	33.50 8.37	37.28 9.32	42.99 10.75	44.74 11.18
Medick + meadow fescue	34.28 8.57	39.81 9.95	44.49 11.12	45.32 11.33
Medick + cat grass	33.04 8.26	38.22 9.55	41.74 10.43	42.74 10.68
Medick + awnless brome	32.08 8.02	36.43 9.11	41.28 10.32	43.20 10.80

Note: numerator – green mass yield, t/ha

denominator – dry matter yield, t/ha

It should be borne in mind that by the 5th year of life, the productivity of medick and meadow-grasses herbage against the background of nitrogen feeding only is significantly reduced. A single application of Borofoska on medick and meadow-grasses herbage in the 3rd year of life at 545 and 920 kg/ha, together with annual nitrogen fertilization N_{30} allows maintaining high productive longevity of the herbage during medium-term use.The laboratory and analytical studies revealed that the biochemical composition of the hay of the 1st cutting of medick and meadow-grasses mixtures was determined both by the species composition of these agrophytocenoses and by the effect of mineral fertilizers. Mineral fertilizers had a noticeable positive effect on the change in the biochemical composition of the hay of cultivated heterogeneous crops of perennial grasses. The authors of the present research found that the content of crude fiber, crude ash, and crude fat was higher in the hay of the 2nd-cutting perennial herbage. The lowest content of crude fiber, crude ash, and crude fat was in the hay of the medick-meadow fescue grass mixture both in the 1st and 2nd cuttings, and the highest results were obtained in the medick-timothy grass mixture. The NFE content in the hay of legume-cereal grass mixtures decreased, and the content of crude fiber in the hay of the 1st cutting of the medick-timothy grass mixture according to the variants of the experiment ranged from 28.18 to 29.85%, the content of the crude ash from 8.42 to 8.92, crude fat from 2.61 to 3.46%, and the NFE content decreased from 32.30 to 27.91%.

In the 2nd cutting, in the hay of the medick-timothy grass mixture the content of crude fiber increased from 28.52% to 29.92% in the variant with the maximum dose of mineral fertilizer ($P_{105}K_{120}$+N_{30} background). According to the variants of the experiment, the content of crude ash increased to 8.98%, crude fat increased to 3.54%, and the content of NFE decreased from 33.54 to 29.91%. In the hay of the medick-meadow fescue grass mixture of the 1st cutting, the content of crude fiber according to the variants was 26.38-27.48%, crude ash 8.24-9.12%, crude fat 2.42-2.86%, and the NFE content decreased from 34.44 to 30.66%. In the 2nd cutting, these indicators were slightly higher – crude fiber was 26.42-27.54%, crude ash 8.24 to 9.12%, crude fat 2.56-2.94%, and the NFE content was 36.02-32.54%.

In terms of biochemical parameters, the medick-cat grass mixture was superior to the medick-meadow fescue mixture but inferior to the medick-timothy mixture both in the 1st and 2nd cutting. In the former, crude fiber was 27.56-29.38%, and crude fiber according to the variants of the experiment ranged 8.36-9.18%, crude fat was 2.46-2.98%, the NFE content ranged 33.06 to 28.52%. In the 2nd cutting, the indicators of biochemical composition were higher: crude fiber according to the variants of the experiment was 27.72-29.54%, crude ash 8.51-9.44%, crude fat 2.80-2.96%, and the NFE content decreased from 34.31% to 30.32%.

The biochemical composition indicators of the hay of the medick-awnless brome mixture in comparison with the medick-cat grass mixture were lower: in the 1st cutting, crude fiber ranged 27.48-28.22%, crude ash 8.72 to 9.24% according to the variants of the experiment, crude fat2.76 to 3.25 %, and the NFE content 32.41 to 29.47%. In the 2nd cutting, these figures were higher.The economic efficiency of cultivating medick with perennial meadow- grasses on the gray forest soil of farmland was calculated based on the results of field experiments and on the developed standard technological maps. According to technological maps, all costs per 1 ha of sown area were attributed to the average annual yield of green mass and hay of single-species and heterogeneous crops of perennial grasses.The economic efficiency was assessed based on a number of indicators: the value of the increase in yield in absolute (t) and value form (RUB), additional costs (RUB), the amount of additional gross production (RUB) , the amount of net income received (RUB), and the size of the profitability of production.One of the factors directly influencing the production profitability level is the value of the yield of the cultivated crop. As a rule, an increase in productivity entails a decrease in all costs of producing a unit (t), and an increase in profitability.When calculating the economic efficiency, the authors took the option with the maximum yield of green mass and dry matter on average for 3 years of research using Borofoska nitrogen-phosphorus-potassium fertilizer at $P_{105}K_{120}$ together with ammonium nitrate at N_{30} (Table 12).

The calculation of the economic efficiency showed that in the control variant without the use of Borofoska, the cost of 1 ton of products exceeded one thousand RUB. The most cost-effective variant was the aftereffect of Borofoska at $P_{105}K_{120}$ together with nitrogen fertilization at N_{30}.

Table 12. Economic efficiency of cultivating medick and meadow-grasses mixtures for green mass (2017-2019)

Indicator	Medick + timothy	Medick + meadow	Medick + cat grass	Medick +

	fescue						awnless brome	
	without Borofoska + N_{30}	$P_{105}K_{120}$ + N_{30}	without Borofoska + N_{30}	$P_{105}K_{120}$ + N_{30}	without Borofoska + N_{30}	$P_{105}K_{120}$ + N_{30}	without Borofoska + N_{30}	$P_{105}K_{120}$ + N_{30}
Area, ha	100	100	100	100	100	100	100	100
Productivity, t/ha	33.50	44.74	34.28	45.32	33.04	42.74	32.08	43.20
Increase in yield, t/ha	-	11.24	-	11.04	-	9.7	-	11.12
Gross production, t	3350	4474	3223	4532	3304	4274	3208	4320
Gross production cost, RUB	1675000	2237000	1614000	2266000	1652000	2137000	1604000	2160000
Production costs, RUB	1268000	1352000	1268000	1352000	1268000	1352000	1268000	1352000
Cost of 1 ton of products, RUB	467	368	485	363	474	385	488	381
Net income, RUB	407000	385000	346000	914000	384000	785000	336000	808000
Production profitability,%	32.1	65.4	27.3	67.6	30.2	58.1	26.5	59.8

The highest indicators of the economic efficiency of green mass production were obtained with grass mixture based on medick and meadow fescue. Thus, the cost of 1 ton of green mass when Borofoska was applied against the background of nitrogen fertilization at 30 kg/ha of active ingredient in the optimal variant, averaged 363 RUB, net income 914,000 RUB with the profitability level of 67.6%. Relatively high indicators of economic efficiency were also obtained with medick and meadow fescue for hay in the optimal variant ($P_{105}K_{120}$ + N_{30}): the cost of 1 ton of products amounted to 979.3 RUB, net income 703,290 RUB, profitability 63.4%.

CONCLUSION

- Based on the results of experimental studies in the southwestern part of the Central region of the RF (Bryansk Oblast), the following conclusions can be drawn:
- The formation of the yield of green mass and dry matter of medick and meadow-grasses mixtures on gray forest soil was determined by the background of mineral nutrition and the species composition of cultivated grass mixtures. On average, over the years of field experiments, the maximum yield (45.32 t/ha) of green mass and dry matter (11.33 t/ha) was provided by medick-meadow fescue grass mixture against the background of the prolonged action of Borofoska in combination with annual nitrogen fertilization at N_{30}.
- On gray forest soil, the highest yield of crude protein (2.145 t/ha) in total for two cuttings on average over the years of research was characteristic of medick-meadow fescue grass mixture with Borofoska at $P_{105}K_{120}$ in aftereffect together with nitrogen fertilization at 30 kg/ha of active ingredient.
- Under the influence of mineral fertilizers, an improvement in the biochemical composition of dry matter of cultivated mixed crops of perennial grasses was noted. The highest rates were characteristic of medick-timothy grass mixture against the background of the aftereffect of Borofoska at $P_{60}K_{120}$ together with nitrogen fertilization at N_{30}. The content of crude fiber in total for two cuttings was 29.88%, crude ash 8.95%, crude fat 3.5%, and NFE 28.91%.
- Calculation of the economic efficiency of cultivating medick and meadow-grasses mixtures for the production of green mass showed that Borofoska at $P_{105}K_{120}$ in aftereffect against the background of nitrogen fertilization at N_{30} kg/ha of active ingredient ensured the highest indicators with medick-meadow fescue grass mixture. The prime cost of 1 ton of green mass was 363 RUB, the net income 914,000 RUB, and profitability 67.6%. When growing medick-meadow fescue grass mixture for hay against the background of Borofoska at $P_{105}K_{120}$ in aftereffect against the background of nitrogen fertilization at N_{30} kg/ha of active ingredient, the prime cost of 1 ton of products was 979.3 RUB, net income 703,290 RUB, profitability 63.4%.
- If medick is cultivated in single-species sowing for green feed, the cost of 1 ton of products in the optimal variant ($P_{60}K_{210}$) was 311.1 RUB (control 423.9), net income 786,000 RUB, the profitability 60.7%. With medick-timothy grass mixture grown for green feed, the cost of 1 ton of products was 291.6 RUB, net income 921,000 RUB, profitability 71.4%. With medick-brome mixture grown for hay against the background of the optimal dose $P_{60}K_{210}$, the cost of 1 ton of production was 964.44 RUB, net income 663,528 RUB, profitability 65.9%.

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