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Single- And Multispecies Farming Ecosystems In Field Forage Production

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Abstract

The research objective was to develop the cultivation of perennial grasses in single-species and heterogeneous crops and in order to improve the biochemical composition of forages. Both the species composition of the grass mixture and the effect of mineral fertilizers on its yield were studied using the field, laboratory, and statistical research methods. An assortment of medick and perennial meadow-grasses on various backgrounds of mineral fertilizers was studied. The legume component consisted of 40 to 50% of medick (Medicago varia Mart.). Meadow-grasses included timothy (Phleum pratense L.), meadow fescue (Festuca pratensis Huds.), cat grass (Dactylis glomerata L.), and awnless brome (Bromus inermis). On average, over the years of field experiments, the maximum yield of green mass and of dry matter was obtained with medick and fescue grass mixture and annual nitrogen fertilization. The highest indices of nutrients were found in the forage mass of the medick and timothy grass mixture.

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

Introduction

Today, one of the issues of topical importance is sustainable development of animal husbandry. It requires intensive agricultural technologies in order to increase the natural resource potential of agrophytocenoses. One of the main obstacles in this sphere is the lack of sufficient feed, both energy-saturated and balanced in terms of the carbohydrates and proteins (Belchenko, Dronov et al., 2016; Belchenko et al., 2020). Meadow-grasses commonly dominate in the structure of perennial grasses. Thorough selection of the species composition and optimal stalk density may become the key to high yields of perennial grasses (Belyak et al., 2016; Dyachenko, Dronov, Zubareva et al., 2015). Medick and perennial meadow-grasses used in single and heterogeneous crops are essential in energy-rich feed production as they help to solve the protein deficiency (Dospekhov, 1985; Dyachenko, Dronov, Dyachenko et al., 2016). It is well known that heterogeneous crops consisting of perennial legumes and cereals have a clear advantage in productivity over single-species agrophytocenoses. It was established that the reason for this is that they absorb fertilizers, soil nutrients, and moisture more efficiently (Dyachenko and Belchenko, 2020; Dyachenko et al., 2020).

Research showed that phosphorus fertilizers are effective in reducing the intake of radionuclides by cultural plants (Belous et al., 2016; Pakshina, Belous, Shapovalov et al., 2017; Pakshina, Belous, Silaev et al., 2017). This said, the phenomenon of biological dilution helps to decrease in the concentration of radiocaesium in products and achieve optimal fertility parameters of soil. The combination of potash fertilizers in large doses and lime materials is the most effective; it allows a 2 to 20 times reduction of the cesium-137 concentration in crops (Belchenko, Torikov et al., 2016; Belous et al., 2010; Belous et al., 2012).

The researchers of the All-Russian Research Institute of Feed Production and Agroecology named after V.R. Williams found that increasing the area of perennial leguminous grasses in single-species and heterogeneous crops to 75-80% increases the yield of feed mass up to 17-18 t/ha. At the same time, it provides a 1.5-1.6 times reduction of the feed cost. This approach may help to solve the problem of provision with high-protein green forage. Besides, the effective use of such natural factors as insulation, minerals and moisture, as well as optimal agricultural techniques make heterogeneous crops a reserve for biological crop production (Belous et al., 2017; Belous et al., 2019). The qualitative parameters of perennial herbage may be influenced by mineral nutrition of plants (Ershov et al., 2017; Gamko et al., 2016; Isakov and Lukashov, 2011).

The intake of radiocaesium by agricultural plants can be significantly reduced by the use of mineral fertilizers, mainly potash (Belchenko S.A., Torikov et al., 2016; Belous et al., 2010; Belous et al., 2016). Acidic soils are limed, the soil solution acidity decreases and the soils are saturated with bases. This reduces the radionuclides mobility in the soil and limits their availability to plants/ this method is highly recommended for the use in contaminated soils (Dyachenko V.V., Dronov A.V., Dyachenko et al., 2015; Shapovalov et al., 2016).

Cultivation of single-species and heterogeneous crops consisting of perennial leguminous grasses helps to produce energy-rich high-protein feed while reducing the use of nitrogen fertilizers

(Anderson and Roed, 1994; Esedulaev and Shmeleva, 2014, 2017). The present research is aimed at developing agricultural techniques for perennial grasses cultivation in single-species and heterogeneous crops, s well as at improving the biochemical composition of forages, depending on both the species composition of the grass mixture and the influence of the mineral fertilizers on the yield in single-species and heterogeneous field agrocenoses of medick and perennial meadow-grasses grown for green forage and hay.

Materials and methods

The field experiment was methodologically based on the principles of agriculture intensification and biologization (Lassey, 1979; Rafferty and Coigan, 1994; Smolders, 1995; Zhy et al., 2000). The research was carried out in 2015-2019 in Bryansk oblast of Russia. The geographical position of Bryansk oblast is in the southwest of Central Russia, with moderately continental climate. Precipitation ranges from 560 to 600 mm, with more than half of it falling during the plant growing season, when the average hydrothermal coefficient amounts to 1.4. The soils are gray forest, light loamy, medium-cultivated, formed on carbonate loess-like loams. The humus horizon is 30-60 cm thick, with the content of humus varying from 2.6 to 3.2%. The soil solution was weakly acidic, the salt extract pH reached 5.2-5.6. Measured by Kirsanov methodology, mobile phosphorus amounted to 250-350 mg, exchangeable potassium – 130-150 mg per 1 kg of soil.

Perennial grasses were researched, which consist of medick and meadow-grass. The proportions of grass mixtures were as follows: 45% legume component and 55% cereal component. The grass was sown under the cover of annual Westerwolds ryegrass (L. westerwoldicum Wittm.), diploid Izorsky variety. Medick (M. varia Mart.) Lugovaya-67 cultivar was used as the legume component. The meadow-grass consisted of 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) SIBNISKHOZ-99 cultivar.

Perennial grasses were sown in the 3rd decade of April with a SN-16 seeder at the speed of 15-16 kg/ha. The sowing area was 30 square meters, with multiple repetition and systematic placement of plots. When cultivating perennial grasses, we used the agricultural technique generally accepted in the given zone. The experiment was two-factor: Factor A – mineral fertilizers and Factor B – the types of grass mixtures.

The grass mixtures productivity and biochemical composition were studied in the following modes: without the mineral fertilizer Borofoska (N_{30}); 272kg/ha of Borofoska ($P_{30}K_{35}+N_{30}$); $P_{60}K_{70}+N_{30}$; and $P_{105}K_{120}+N_{30}$. Borofoska was introduced one time in a season in early spring before the perennial grasses start growing. Also, it was simultaneously added to the fertilizer – ammonium nitrate at the rate of 89 kg/ha (N_{30}).

The crop was accounted plot by plot. The green mass from 1 square meter was dried up to a constant weight. The technique was applied in compliance with the Guidelines for conducting field experiments with feed crops (Guidelines for conducting …, 1997). The results were statistically analyzed according to B.A. Dospekhov (1985) methodology. Laboratory and analytical stages complied with those generally accepted for agrochemical research at the Public Center of Instrumental and Scientific Equipment at Bryansk State Agrarian University. The following components were determined: dry matter (coefficient of 6.25 for conversion to crude protein); crude cellular tissue, by Geneberg and Shtoman in the modification of VNIIK; and crude fat by Rudkovsky. Nitrogen-free extractive substances were calculated according to the formula: NFE = 100 – (moisture + CP + CCT + CA + CFa), where CP is crude protein, CCT is crude cellular tissue, CA is crude ash, and CFa is crude fat.

The experimental results were processed using variance and correlation analysis with specialized computer software (Excel 7.0, Statistic 7.0, NCSS-2000) (Dyachenko, Dronov, Zubareva et al., 2015).

Results

The research allows stating that the use of Borofoska mineral fertilizer together 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). In most cases, even a relatively small dose of Borofoska ($P_{30}K_{35}$) used in combination with nitrogen fertilization results in a statistically significant increase in the yield of green mass of medick and meadow-grasses mixtures of the 3rd year of life in the 1st mowing. Higher doses of Borofoska ($P_{60}K_{70}$ and $P_{105}K_{120}$) together with ammonium nitrate provide a significant increase in the green mass yield – 1.63 to 6.57 t/ha.

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 1.62				

HCP_{05} for Factor B (grass mixture) – 1.62
HCP_{05} for particular differences – 3.23
Experiment accuracy, % – 3.10

The highest productivity in the 1st mowing was shown by the medick+timothy mixture; the green mass yield was from 23.8 to 25.43 t/ha, but the yield increase due to Borofoska and ammonium nitrate was within the experimental error. Other mixtures showed a comparatively smaller green mass yield – 12.53 to 23.29 t/ha, but their responsiveness to Borofoska was reliable. The effect of high doses of Borofoska ($P_{60}K_{70}$ and $P_{105}K_{120}$) was most expressed in the medick+awnless brome mixture, with the 36–52% increase compared with the control amounts. The responsiveness to Borofoska in medick+meadow fescue and medick+cat grass appeared to be much lower.

The 2nd mowing showed that Borofoska mineral fertilizer also positively affected the feed mass yield, but much less than in the 1st mowing – 12 to 19 t/ha, depending on the grass mixture composition and the dose of mineral fertilizers (Table 2).

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 0.37				
HCP_{05} for Factor B (grass mixture) – 0.37				
HCP_{05} for particular differences – 0.74				
Experiment accuracy, % – 2.1				

The use of Borofoska mineral fertilizer even at the rate of 272 kg/ha ($P_{30}K_{35}$) provided a statistically significant yield increase in the 2nd mowing. The effect of ammonium nitrate on the 2nd mowing (at the end of July) was insignificant, and the increase in the yield of grass mixtures is solely due to the effect of Borofoska. It is important to note a significant increase in the yield of meadow fescue grass mixtures in all modes of fertilizer use.

The prolonged influence of Borofoska mineral fertilizer clearly showed during the 3rd mowing of medick and meadow-grasses (Table 3).

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 0.38				
HCP_{05} for Factor B (grass mixture) – 0.38				
HCP_{05} for particular differences – 0.82				
Experiment accuracy, % – 2.84				

Thus, the Borofoska mineral fertilizer in the studied doses provided a statistically significant increase of 1.31 to 3.13 t/ha in the green mass yield compared to unfertilized soil. As one can see, even 272 kg/ha ($P_{30}K_{35}$) of Borofoska mineral fertilizer had a significant effect on the green mass yield.

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

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

Discussion

In the agricultural and climatic conditions of Bryansk oblast of Russia, medick and meadow-grasses of the 3rd year of life provide a high yield of feed mass on gray forest soil (Table 4, Fig. 1). For example, in 2017 (as a sum of three mowings) the yield ranged from 31 to 58 t/ha of green mass depending on the grass mixture composition and the mineral nutrition mode. The use of Borofoska mineral fertilizer and ammonium nitrate significantly allows increasing the yield as early as in the 1st year. For certain grass mixtures, even such a small dose of Borofoska as 272 kg/ha ($P_{30}K_{35}$) combined with ammonium nitrate (N_{30}) increased the yield from 3.88 to 7.5 tons/ha.

Together with ammonium nitrate, 545 and 920 kg/ha of Borofoska ($P_{60}K_{70}$ and $P_{105}K_{120}$) give a larger increase in yield – from 8 to 11 t/ha.

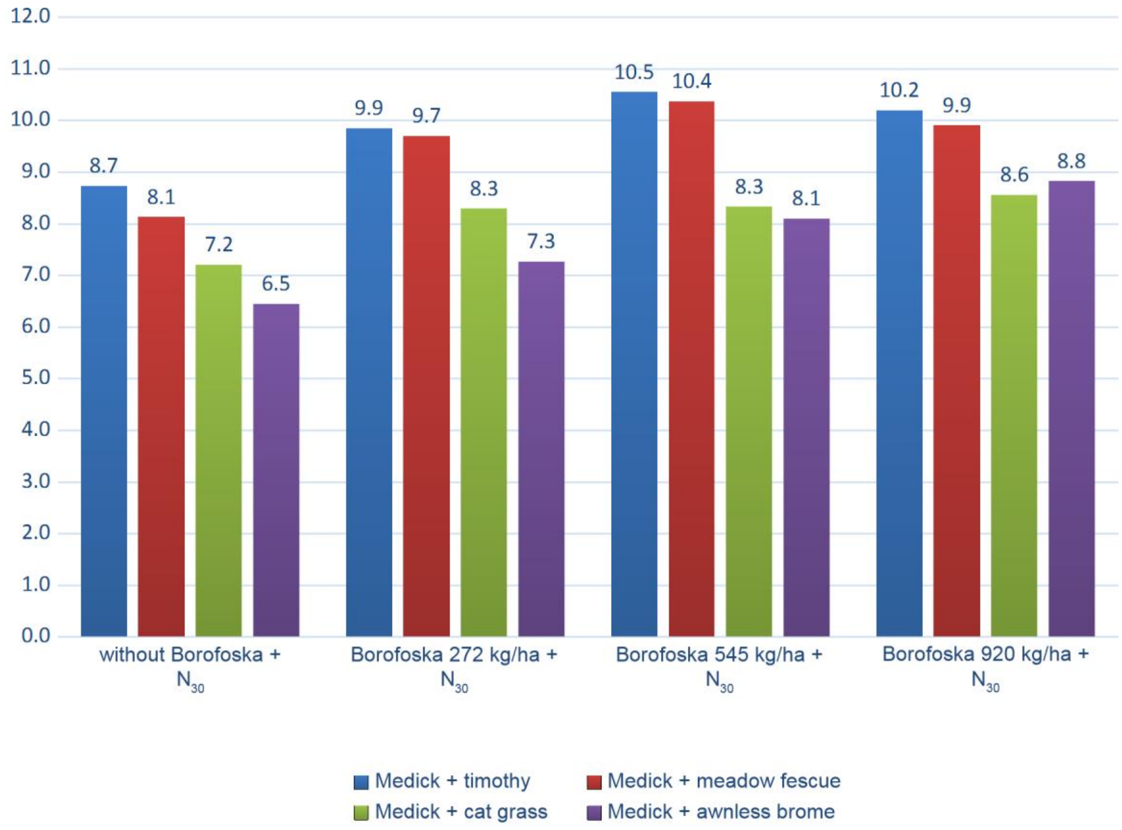

Fig. 1. Dry matter yield of medick and meadow-grasses mixtures (3rd year of life), t/ha

The same combination of mineral fertilizers also significantly increased the dry matter yield of medick mixtures with timothy and meadow fescue (up to 10 t/ha and more) and with cat grass (up to 8 t/ha and more). As for the medick and awnless brome mixture, the dry matter yield exceeding 8 t/ha was obtained only with the use of Borofoska at 545 and 920 kg/ha.

The introduction of Borofoska mineral fertilizer to a certain extent changed the botanical composition of herbage in the 3rd year of life. The share of medick increased by 3–12%, the share of meadow-grasses proportionally decreased. As a result, medick constituted 74.8–81.7% of the total mass of the grass yield, while the share of meadow-grass was 17.8–26.9%. The share of weeds was 0.4–1.2%.

Despite a dry winter, in 2018 (4th year of life) the overwintering of medick and meadow-grasses passed rather normally. In early spring, all plots were fertilized with nitrogen in the calculated dose of N_{30} (about 90 kg/ha in physical terms), early spring harrowing was carried out. The use of medick and meadow-grasses mixtures of the 4th year of life was transferred into a two-mowing scheme, technological measures for hay making was carried out.

According to the experiments, the aftereffect of Borofoska mineral fertilizer combined with ammonium nitrate (introduced in the year of research) significantly increased the green mass yield of medick and meadow-grasses mixtures in comparison with the mode without Borofoska (Table 5). The aftereffect of Borofoska in the as small amount as 272 kg/ha in the 2nd year of application provides a statistically significant increase of green mass – 2.09 to 3.16 t/ha.

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 1.58				
HCP_{05} for Factor B (grass mixture) – 1.58				
HCP_{05} for particular differences – 3.12				
Experiment accuracy, % – 2.90				

The small amount of Borofoska mineral fertilizer provided the highest aftereffect on the mixture of medick and awnless brome. The amounts of Borofoska at 545 and 920 kg/ha ($P_{60}K_{70}$ and $P_{105}K_{120}$) together with ammonium nitrate gave an even more significant increase in yield – 4.76 to 6.98 t/ha. In this mode, the highest increase in the yield of the 1st mowing was found for the mixture of medick and timothy (Table 6).

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

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 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 showed a statistically significant increase in the green mass yield compared to the mode without fertilizers – from 1.39 to 4.49 t/ha, depending on the grass mixture. The aftereffect of Borofoska mineral fertilizer at 545 and 920 kg/ha ($P_{60}K_{70}$ and $P_{105}K_{120}$) produced an even greater increase in yield – 5.16 to 6.85 t/ha.

Evaluating the effectiveness of the 1st year aftereffect of Borofoska mineral fertilizer 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 2018 growing season (Table 7). The aftereffect of Borofoska at 272 kg/ha increased the yield of the studied mixtures from 3.5 to 7.1 t/ha; larger quantities, for example, 545 and 920 kg/ha, provide an even more significant increase – 10.5 to 13.0 t/ha of green mass. It is worth noting that no significant differences in the green mass yield for two mowings from the aftereffect of $P_{60}K_{70}$ and $P_{105}K_{120}$ modes were observed for most of the studied mixtures, except for the medick+timothy mixture – its green mass yield was the highest under the $P_{105}K_{120}$ mode (about 45 t/ha).

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

Factor B	Factor A (with mineral fertilizers)

(grass mixture)	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 (with mineral fertilizers) – 1.98				
HCP_{05} for Factor B (grass mixture) – 1.98				
HCP_{05} for particular differences – 4.57				
Experiment accuracy, % – 3.01				

The aftereffect of Borofoska mineral fertilizer also positively influenced the dry matter yield during the 1st year (Fig. 2). Nitrogen fertilization without the aftereffect of Borofoska yielded from 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% and more. The aftereffect of Borofoska at 545 and 920 kg/ha provided more than 10.5-11.0 t/ha of dry matter yield.

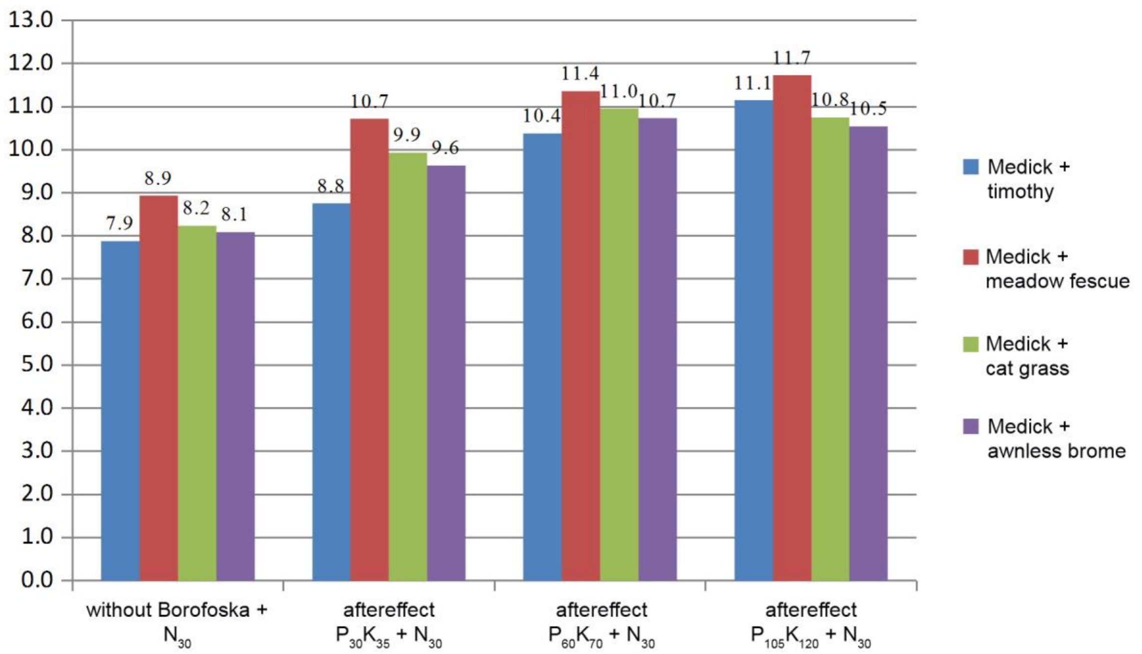

Fig. 2. Dry matter yield of medick and meadow-grasses mixtures (4th year of life), t/ha

In 2019 (5th year of life), medick, awnless brome and cat grass overwintered well, while meadow fescue and timothy were largely eliminated. In early spring, all experimental plots received nitrogen fertilization with the calculated dose of N_{30} (about 90 kg/ha of ammonium nitrate in physical terms), early spring harrowing was performed. Hay was made of medick and meadow-grasses mixtures of the 5th year of life according to the two-mowing scheme.

The 2nd year of the aftereffect of Borofoska mineral fertilizer at 545 and 920 kg/ha in combination with early spring nitrogen fertilization gave a statistically significant increase in the green mass yield of medick and meadow-grasses mixtures compared with the mode without Borofoska (Table 8). The aftereffect of Borofoska at 272 kg/ha in the 3rd year of application, as a rule, did not provide a statistically significant increase.

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 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 2nd year of the aftereffect of Borofoska mineral fertilizer 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 smaller, although these mixtures were generally 6–10% more productive. This was due to the fact that timothy and fescue disappeared in the herbage by the 5th year of life, and the yield mainly consisted of medick.

The yield of grass mixtures of the 5th year of life confirms the effectiveness of the prolonged action of high doses of Borofoska mineral fertilizer (Table 9). At that, 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 enables to increase the yield of medick and meadow-grasses mixtures of the 5th year of life by 34–45% compared to the mode without Borofoska. Also, it should be noted that grass mixtures of medick with cat grass and awnless brome provide a higher yield – about 20 t/ha.

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 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 mineral fertilizer in combination with ammonium nitrate (N_{30}), one may notice a significant positive effect of this agricultural method on the yield of feed mass in the 2019 season (Table 10, Fig. 3).

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 (with mineral fertilizers) – 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 increased insignificantly from 2.0 to 3.6 t/ha due to the 2nd year aftereffect of Borofoska at 272 kg/ha, which is almost within the limits of statistical significance. The aftereffect of Borofoska mineral fertilizer 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 obtained as the aftereffect of Borofoska at 920 kg/ha.

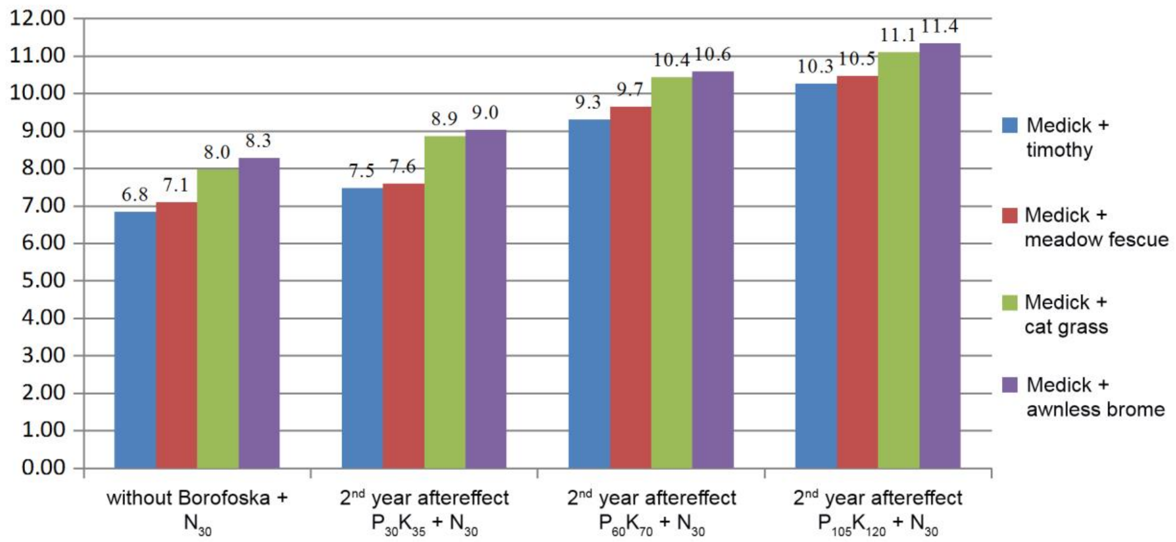

Fig. 3. Dry matter yield of medick and meadow-grasses mixtures (5th year of life), t/ha

The 2nd year aftereffect of Borofoska mineral fertilizer positively influenced the dry matter yield of medick and meadow-grasses mixtures (Fig. 3). One-time fertilization with nitrogen 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, during 3–5 years of use, medick and meadow-grasses mixtures on gray forest soil (Bryansk oblast), provided 40–45 t/ha of green mass and 10–11 t/ha of dry matter after a single introduction of Borofoska mineral fertilizer at 545 and 920 kg/ha, together with annual nitrogen fertilization (on average for the years 2017–2019) (Table 11).

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

Factor B (grass mixture)	Factor A (with mineral fertilizers)			
	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 is worth noting that by the 5th year of life, the productivity of medick and meadow-grasses herbage under the nitrogen feeding alone is significantly reduced. To maintain productive longevity of the herbage medium-term, it is sufficient to introduce Borofoska mineral fertilizer on medick and meadow-grasses herbage once in the 3rd year of life at 545 and 920 kg/ha and carry out annual nitrogen fertilization with N_{30}.

Laboratory and analytical research showed that the biochemical parameters of the medick and meadow-grasses hay of the 1st mowing influenced both on the species composition of these agrophytocenoses and on the mineral fertilizers. The latter had an expressed positive effect on the biochemical composition of the hay made of perennial grasses. It was found that the content of crude cellular tissue, crude ash, and crude fat was higher in the hay of the 2nd mowing perennial herbage. The lowest content of crude cellular tissue, crude ash, and crude fat was observed in the hay of the medick-meadow fescue grass mixture both in the 1st and 2nd mowings, and the highest results were obtained in the medick-timothy grass mixture. The content of nitrogen-free extractive substances in the hay of legume-cereal grass mixtures decreased, and the content of crude cellular tissue in the hay of the 1st mowing of the medick-timothy grass mixture ranged from 28.18 to 29.85%. The content of the crude ash varied from 8.42 to 8.92, of crude fat – from 2.61 to 3.46%, and the content of nitrogen-free extractive substances decreased from 32.30 to 27.91%.

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

As for the 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 mowing. In the former, crude cellular tissue constituted 27.56–29.38%, and crude cellular tissue ranged from 8.36 to 9.18% in various modes, the content of crude fat was 2.46–2.98%, and of nitrogen-free extractive substances – 33.06 to 28.52%. In the 2nd mowing, the biochemical parameters were higher: the content of crude cellular tissue ranged 27.72–29.54%, of crude ash – 8.51–9.44%, of crude fat – 2.80–2.96%, and the content of nitrogen-free extractive substances decreased from 34.31% to 30.32%.

The indicators of biochemical composition of the medick-awnless brome mixture hay in comparison with the medick-cat grass mixture hay were lower: in the 1st mowing, crude cellular tissue ranged from 27.48 to 28.22%, crude ash – from 8.72 to 9.24% in various modes, crude fat – from 2.76 to 3.25 %, and the content of nitrogen-free extractive substances – from 32.41 to 29.47%. In the 2nd mowing, these parameters were higher.

The results of field experiments and the developed standard technological maps allowed calculating the economic efficiency of cultivating medick with perennial meadow-grasses on the gray forest soil. 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 absolute (t) and cost (RUB) yield increase, the surplus costs (RUB), the amount of surplus gross production (RUB), the net income received (RUB), and the production profitability.

One of the factors directly influencing the production profitability level is the cultivated crop yield. As a rule, a yield increase leads to a decrease in all production costs per unit (t) and an increase in profitability (Belous et al., 2012).

The economic efficiency was calculated for the mode with the maximum yield of green mass and dry matter during 3 years on average using Borofoska nitrogen-phosphorus-potassium fertilizer at $P_{105}K_{120}$ together with ammonium nitrate at N_{30} (Table 12).

According to the economic efficiency calculation, in the control variant without the use of Borofoska mineral fertilizer, the cost of 1 ton of products exceeded 1,000 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 fescue		Medick + cat grass		Medick + 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
Yield increase, t/ha	-	11.24	-	11.04	-	9.7	-	11.12
Gross production, t	3,350	4,474	3,223	4,532	3,304	4,274	3,208	4,320
Gross production cost, RUB	1,675,000	2,237,000	1,614,000	2,266,000	1,652,000	2,137,000	1,604,000	2,160,000
Production costs, RUB	1,268,000	1,352,000	1,268,000	1,352,000	1,268,000	1,352,000	1,268,000	1,352,000
Cost of 1 ton of products, RUB	467	368	485	363	474	385	488	381
Net income, RUB	407,000	885,000	346,000	914,000	384,000	785,000	336,000	808,000
Production profitability,%	32.1	65.4	27.3	67.6	30.2	58.1	26.5	59.8

The green mass production was most efficient with the grass mixture of medick and meadow fescue. When Borofoska mineral fertilizer was applied against the background of nitrogen fertilization at 30 kg/ha of active ingredient in the optimal variant, the cost of 1 ton of green mass averaged 363 RUB, the net income was 914,000 RUB with the profitability level of 67.6%.

Relatively high indicators of economic efficiency were also obtained with medick and meadow fescue grown for hay under the optimal mode ($P_{105}K_{120}$ + N_{30}): the cost of 1 ton of products amounted to 979.3 RUB, the net income was 703,290 RUB, profitability – 63.4%.

Conclusion

The experimental research carried out in the southwest of Central Russia (Bryansk oblast) allows making the following conclusions:

1. The yield of green mass and dry matter of medick and meadow-grasses mixtures on gray forest soil depends on mineral nutrition and the species composition of the grass mixtures. The maximum yield of green mass (45.32 t/ha) and dry matter (11.33 t/ha) was provided by medick-meadow fescue grass mixture under the prolonged action of Borofoska mineral fertilizer and annual fertilization with nitrogen at N_{30}.

2. On gray forest soil, medick-meadow fescue grass mixture provided the highest yield of crude protein (2.145 t/ha) as a sum of two mowings, on average over the years of research, with Borofoska at $P_{105}K_{120}$ in aftereffect with nitrogen fertilization at 30 kg/ha.

3. The biochemical composition of the dry matter of cultivated perennial grasses significantly improved under the influence of mineral fertilizers. The best parameters were obtained for medick-timothy grass mixture as the aftereffect of Borofoska mineral fertilizer at $P_{60}K_{120}$ combined with nitrogen fertilization at N_{30}. The content of crude cellular tissue as a sum of two mowings was 29.88%, of crude ash – 8.95%, of crude fat – 3.5%, and the content of nitrogen-free extractive substances – 28.91%.

4. The economic efficiency of cultivating medick and meadow-grasses mixtures for the green mass was calculated. Borofoska mineral fertilizer at $P_{105}K_{120}$ in aftereffect with nitrogen fertilization at N_{30} kg/ha of active ingredient was the most effective for medick-meadow fescue grass mixture. The 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 with Borofoska at $P_{105}K_{120}$ in aftereffect and nitrogen fertilization at N_{30} kg/ha of active ingredient, the cost of 1 ton of products was 979.3 RUB, net income – 703,290 RUB, and profitability – 63.4%.

5. Cultivation of medick for green feed as a single species under the optimal mode ($P_{60}K_{210}$) provides the cost of 1 ton of product equal to 311.1 RUB (control 423.9), net income – 786,000 RUB, and profitability – 60.7%. With medick-timothy grass mixture grown for green feed, the cost of 1 ton of product amounted to 291.6 RUB, net income – 921,000 RUB, and profitability – 71.4%. When medick-brome mixture was grown for hay under the optimal mode $P_{60}K_{210}$, the cost of 1 ton of production was 964.44 RUB, net income – 663,528 RUB, and profitability – 65.9%.

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