Agro-energy efficiency of using new zoned varieties to create cultivated pastures in the forest zone of the European part of Russia

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Abstract. The agro-energy efficiency of using new varieties of creeping clover (Lugovik), meadow clover (Veteran) and alfalfa changeable (Agnia) in comparison with previously zoned varieties of these species (respectively – VIC 70, Tetraploid VIC and Pasture 88) is determined on the basis of the results on productivity and total anthropogenic costs obtained in the field experience based on the dry-fall type of pastures occupying 92% in the Central region of the European part of Russia. The assessment of agro-energy efficiency was determined according to the methods approved by the Russian Academy of Agricultural Sciences. Taking into account a set of indicators (productivity of improved land for the production of exchange energy in GJ/ha and products produced in MJ per 1 GJ, reducing total anthropogenic costs in GJ/ha and increasing their payback), the high efficiency of new varieties is established and the principle of changing varieties in meadow forage production is scientifically justified. At the same time, the effectiveness of previously zoned varieties of leguminous grasses has also been confirmed, which allows increasing their seed production in the regions due to the high demand not only for field, but also for meadow grass.

1. Introduction

The modern concept of ecology of plant agroecosystems includes the study and assessment of bioenergetic processes that change as a result of human activity. The book "fundamentals of ecology" published in Russia by Julius Odum had a great influence on the development of research in this area [1]. The pushchinsky scientific center - Institute of soil science and photosynthesis conducted ecological and energy research in the field of agriculture to optimize the productivity of agroecosystems [2], as well as the V. R. Williams Institute of feed in the field of meadow agroecosystems. As a result, methods were published: on agro-energy assessment of feed production technologies and systems [3], as well as on the study of energy flows in meadow agroecosystems, and the determination of natural factors [4]. Natural factors of meadow agroecosystems, along with the use of photosynthetically active solar radiation, include the following indicators: an increase in the duration of use of sown grass stands...
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(properties of species longevity and self – renewal of phytocenoses), the supply of biological nitrogen, and changes in soil fertility. Based on previous studies in the forest zone of the European part of Russia, it was found that the production of 4.0-4.5 t / ha of dry matter of pasture feed (on average for 5 years) can be obtained on pastures with legumes and grasses without nitrogen fertilizers [5]. In addition, in zootechnical experiments, when assessing the productivity of animals, the quality of milk and its processed products, an improvement in taste and technological indicators was found in comparison with feeding cows during the stall period and when grazing on grass stands [6]. Thanks to the use of a new method of conjugate variety-microbial selection, the Federal research center "V. R. Williams VIC" has created more productive varieties of creeping clover, meadow clover and variable alfalfa, included in the State register of breeding achievements [7-15]. The results of their agro-energy efficiency in the composition of recommended grass mixtures with cereal species in the pasture mode of use are presented for the first time in this article.

Materials and methods

The scheme of the experiment provides for the study of three types and six varieties of legumes, the effectiveness of seed inoculation with complementary strains of nodule bacteria. The scheme of the experiment includes option 1 (grassy herbage against the background of P60K120), which allows you to determine the productivity of the herbage due to nitrogen intake from the soil; this option is also intended to establish the effectiveness of legume-grassy herbage on the influence of legumes on productivity. Option 2 (grassland on the background of N135PK) allows you to compare the effect of a mineral nitrogen fertilizer and a biological nitrogen source. When studying grass mixtures with creeping clover, two varieties were used: basic-VIC 70, previously included in grass mixtures, and meadow, sown for the first time (variants 3-6). Options 3 and 5 provide for the study of the effectiveness of natural inoculation (due to soil microflora [16]), and options 4 and 6 – to determine the effectiveness of pre-sowing seed inoculation with a complementary strain of KR-2 [17].

Variants 7-10 with meadow clover are designed to compare varieties of Tetraploid VETCH (basic grass mixture) and Veteran (new grass mix) on different backgrounds. Variants 8 and 10 provide for inoculation of seeds with strains 348A and KR-8, respectively, for varieties [18-19].

Alfalfa-grass stands in the experiment are represented by variants 11-14 with varieties of variable alfalfa Pasture 88 (basic grass mix) and Agnia (new grass mix). In variants 12 and 14, an additional technique is evaluated – inoculation of seeds with the 404b strain [20].

The field experience was laid in 2014 at the experimental base of the research Institute of feed. The soil is sod-podzolic, medium loamy; before laying the field experiment, it contained 2.26 % humus, 0.14 % total nitrogen, 62 mg / kg P2O5 and 53 mg / kg K2O, pH5, 6,05,9 (as a result of liming in previous years). Therefore, all grass mixtures were studied against the background of P60K150, in option 2 they were additionally added for each cycle N45 (three accounting cycles per season-N135). Tillage at the experimental site included: autumn sod disking of the BDT-3 pasture (in two tracks) and plowing (PLN-4-35) in 2013; spring 2014. The formation was cut by disking (in two directions), the site layout, pre – sowing rolling of the soil with a ring roller, and after sowing-with a smooth roller KVG-1,4. Seeding of grass mixtures was carried out on 15.05.2014 at random in order to create a closed herbage. The yield was taken into account in the phases of entering the tube of cereals and legume stalking, i.e., according to the principle of medium and late paddock in the pasture conveyor (three cycles per season). Agro-energy assessment of techniques and technologies was carried out according to the method adopted in meadow farming [21; 22], approved by the Russian Academy of agricultural Sciences. The applied method of agro-energy assessment allows us to compare pasture productivity and total anthropogenic energy costs in single indicators (GJ/ha), determine the most expensive links in the technology in order to justify energy saving methods, as well as the impact of anthropogenic costs on the use of natural factors. These problems were solved on the example of comparing legume-grass and grass swards.
2. Results and discussion

Agrometeorological conditions, according to the weather station of the Federal research center "VIC named after V. R. Williams", differed markedly over the years of research. The growing seasons of 2015 and 2016 were favorable for the growth of perennial grasses, the content of legumes in the grass stands was the highest (4.5-5.3 t / ha SV for creeping clover, 8.0-8.6 t/ha SV for meadow clover and 5.9-6.2 t/ha SV for alfalfa variable in accordance with the studied varieties). The growing season of 2017 was lower than average in terms of heat supply and precipitation was 25% less than normal; in 2018, the average daily air temperature was 15% higher than normal, and the hydrothermal coefficient decreased from 1.4 to 1.1. Therefore, the yield of legumes, especially creeping clover on average for these 2 years decreased by 3.0-3.6 times compared to the previous two-year period. In 2019, the number of rainy days was 1.7 times higher than the average, while the yield of the Lugovik variety was 1.7 times higher than that of the VIC 70 variety [23]. For meadow clover, a decrease of 5-6 times in the second period compared to the first period was established and this indicator remained at a low level (9-10%) in 2019. For variable alfalfa the yield dynamics by period and year differed from the indicators for clovers: the decrease in yield in the second period was 2.4-2.9 times, but in the fifth year of use (in 2019), the yield exceeded meadow clover by 3.9-6.0 times. Therefore, we can predict that by the combination of these mixtures in different pens Gurtovoy phase in the practice of grassland management, will manifest their compensatory role in the first two years of use, more productive swards with red clover (11,0-12,3 t/ha DM), 3-5 year use (4-6 a year) the yield of alfalfa-grass swards (6.0 to 6.7 t/ha DM) was statistically significantly superior to clever-grass herbage (4.7-5.3 t/ha SV, respectively, with the reference and new varieties). Therefore, the creation of a variety of legumes and grasses due to the biological characteristics of the species and their different reactions to the weather conditions of the growing seasons contributes to better provision of animals with green food. The exchange energy content was 9.9 MJ / kg SV in grass mixtures against the background of P_60 K_150 and 10.1 MJ/kg SV against the background of additional application of ammonium nitrate at a dose of N_135, in grass mixtures with creeping clover 10.1-10.2 MJ/kg SV, with meadow clover 10.4 MJ/kg SV, in alfalfa-cereals 10.1 MJ/kg SV [24].

The production of exchange energy in pasture feed per 1 ha, taking into account the first year of pasture creation (2014), was calculated over 6 years, taking into account capital investments for their creation, which is shown in the table.

| Version of experience. | Productivity of 1 ha | Share of natural factors in the structure of OE production from 1 ha | Agro-energy coefficient, % | Unit costs, MJ per 1 GJ OE |
|------------------------|---------------------|---------------------------------------------------------------|--------------------------|--------------------------|
| (composition of the herb mixture) | (grade a bean kind) | (exchange energy, GJ) | (exchange energy expenditure, GJ / ha) | (% GJ) | (% GJ) | (MJ / GJ) | (GJ) | (GJ) |
| fescue + Timofeevka, background PK | - | 31.9 | 100 | 7.7 | 24.2 | 76 | 414 | 241 |
| fescue + Timofeevka, background NPK | - | 68.9 | 216 | 20.7 | 48.2 | 70 | 333 | 300 |

Natural inoculation

| Cereals + VIC 70 | 56.4 | 177 | 8.2 | 48.6 | 86 | 680 | 144 |
|------------------|------|-----|-----|-------|----|-----|-----|
| Lugovik          | 61.5 | 193 | 8.4 | 53.1 | 87 | 732 | 137 |
The productivity of grasses against the background of P_60K_150 (31.9 GJ/ha on average for 6 years) was limited due to insufficient nitrogen supply from sod-podzolic soil, when applying additional fertilizing with mineral fertilizers at a dose of N135, this indicator increased by 116%. On legumes and grasses, productivity under the influence of a biological nitrogen source also increased by 77-115% with the participation of creeping clover, by 77-112% due to the influence of meadow clover – by 85-115%, with the participation of alfalfa variable – by 79-99%.

The average annual effect of inoculation with complementary Rhizobium strains for an average of 6 years was 6.0-7.1 GJ/ha on grass stands with creeping clover, 4.3-4.5 GJ/ha with meadow clover, and 4.3-4.5 GJ/ha with variable alfalfa (respectively with the evaluated varieties). However, taking into account that pre-sowing inoculation of seeds was performed once (in 2014), the total effect for 6 years for these species reached 42.6, 27.0 and 30.0 GJ/ha on these herbages.

The average annual total anthropogenic costs on legumes and grasses were 6-10% higher than on grasses (fon RK), but they were 2.4-2.5 times less than when applying top dressing with nitrogen tucks. In the structure of total anthropogenic expenditures on legume and cereal grass stands, 30-35% are capital investments (tilling-tillage, seeds, preparing them for sowing, fencing the territory), 65-70% are annual production (current) costs (grazing, fertilizing and mowing grass stands after grazing, repairing fences). When applying nitrogen fertilizers on grassland, current costs increase three times due to the energy intensity of the production of nitrogen fertilizers (8.68 MJ/1 kg of the active substance of ammonium nitrate). Therefore, due to legumes in grass stands, an energy saving effect is achieved annually – 12.2-12.5 GJ/ha. This is due to a 2.2-2.5-fold increase in the use of renewable natural energy sources from 24.0 (grassland against the background of the Republic of Kazakhstan) to 55-60 GJ/ha on leguminous grasslands.

The agro-energy coefficient of recoupment of total energy costs due to the production of exchange energy in the crop of grasses in the first variant (control) was 412%, when fertilizing with nitrogen fertilizers, this indicator decreased to 327%, and on legume-grasses – increased to 760-790% on grasses.
stands with creeping clover, 766-816% on grass stands with meadow clover and 730-747% with alfalfa variable. The increase in this indicator confirms the advantage of new varieties of legumes in comparison with previously zoned varieties, although they can also be used for grazing pastures with organized seed production and ensuring the needs of the economy with these seeds. The cost of presowing inoculation of legume seeds pays off 5-6 times in one year of use. Therefore, this technique should be mandatory in meadow farming.

The specific costs of anthropogenic energy for the production of 1 GJ of exchange energy contained in pasture grass (CB) on grass stands averaged 241-300 MJ over 6 years, decreased to 144-126 MJ on grass stands with creeping clover, to 140-123 MJ when using meadow clover, and to 147-133 MJ in grass stands with alfalfa. At the same time, the advantage of new varieties in comparison with previously zoned ones is also confirmed. This provides a scientific justification for the prospects of variety substitution in the seed production of perennial legumes, and in the transition period – the feasibility of continuing the production of seeds of basic varieties.

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