Cultivation of legume-grain agrocenoses for the purpose of resource saving in forage production

S Bevz and E Toshkina
Yaroslav-the-Wise Novgorod State University, B. Peterburgskaya Street, 41
173003 Veliky Novgorod, Russia

E-mail: bewzswetlana@mail.ru

Abstract. In order to identify more cost-effective technologies and cheaply grown crops, it is possible to compare various options on the basis of their total energy consumption and agroenergetics ratio. The analysis of the energy parameters of the technology of field and meadow forage production showed that the energy cost of cultivation of grain and legume-grain agrocenoses and their structure varied significantly and depended on the composition of cenoses, different types and doses of fertilizers, the type and quantity of seeds of annual crops and their energy consumption. In all agrocenoses, the operational energy costs were not equally distributed. The lowest cost accounted for labor (10 to 30%), and the highest cost (60 to 70%) – for fuel. The introduction of the legume component that does not require the application of energy-intensive nitrogen fertilizers to the field and meadow agrocenoses significantly reduces the energy consumption for their cultivation. This has affected the agroenergetics ratio of various technologies. Due to the inclusion of Vicia sativa (tare) in the field cenosis, the agroenergetics ratio increased by 20%, and the inclusion of clover in the meadow agrocenosis has led to the two-fold increase of the agroenergetics ratio, compared with grain cenoses. That is, when cultivating legume-grain grass stand, the greatest agroenergetics ratio was achieved. The yield of exchange energy is almost 9 times higher than the energy spent on the cultivation of this agrocenosis. For the purpose of resource saving in forage production and preparation of high-quality forage, it is expedient to cultivate legume-grain agrocenoses. The introduction of the legume component in the field and meadow agrocenoses will not only increase the nutritional value of the forage, but also rise the agroenergetics ratio.

1. Introduction
Nowadays, forage production should be based on the principles of resource saving and methods of improving the environmental safety of agroecosystems [2, 4].

Obtaining cheap and high-quality forage is an important factor in reducing the cost of livestock products, increasing its competitiveness and accessibility to consumers. To solve this problem, it is important to maximize the agroenergetics ratio of growing crops and increase the nutrient content in the forage, primarily of protein, which determines the level of feed costs per unit of production [1, 6].

On the basis of adaptive intensification of field and meadow forage production it is possible to significantly increase the production of high-quality forage through the use of advanced technologies of cultivation of forage crops, improving the structure and quality of feed. [5, 7].
2. Methods and Equipment

In order to study the influence of the composition of field and meadow agrocenoses on their productivity, field experiments were carried out on the lands of LLC “Ermolinskoye” of the Novgorod region in 12 km from the city of Veliky Novgorod. Soil type – sod-podzolic with high nutrient content and weakly acidic reaction of the soil solution. The mechanical composition of the soil of the experimental plot is medium-loamy, belongs to the category of high – cultivated. The studies were conducted during 2015 - 2018.

The objects of research of field agrocenoses were as follows: single-species sowing of Avena sativa (common oats); joint and mixed sowing of oats with Vicia sativa (tare) in different ratios (in brackets - the seeding rate). The scheme of experience included the following options:

- Common oats (250 kg/ha);
- Oats + tare (125 kg/ha + 100 kg/ha);
- Oats + tare (175 kg/ha + 50 kg/ha);
- Oats + tare (250 kg/ha + 200 kg/ha).

In meadow agrocenoses, three-species grass stand and legume-grain mixtures with the inclusion of different varieties of meadow clover were studied. The scheme of experience included the following options:

- Meadow fescue (12 kg/ha) + timothy grass (9 kg/ha) + awnless brome grass (10 kg/ha);
- Meadow fescue (7 kg/ha) + timothy grass (5 kg/ha) + awnless brome grass (7 kg/ha) + meadow clover Sedum (10 kg/ha);
- Meadow fescue (7 kg/ha) + timothy grass (5 kg/ha) + awnless brome grass (7 kg/ha) + meadow clover Carmine (10 kg/ha).

Trial establishment, observation, monitoring of yield and agro-energetics assessment of the effectiveness of technologies were carried out according to the techniques of Russian Scientific School of Forage Production. [3].

Monitoring of yield in the experiments was conducted by the cut-sample method in the phase of panicle formation and flowering of legumes. The account of a crop on meadow grass stands was carried out since the second year of life. Before trial establishment, the agrochemical analysis of the soil was conducted. The PH of the salt was identified using an electrometric method, mobile phosphorus according to Kir'sanov; exchange potassium on flame photometer. All the analyses were made at the station of agrochemical service “Novgorodskaya”.

Weather conditions in the years of the experiments were typical for the Novgorod region, with the exception for 2018, which was characterized as a cold and excessively waterlogged. Therefore, the yield data for 2018 were not taken into account.

3. Results

In order to identify more cost-effective technologies and cheaply grown crops, it is possible to compare various options on the basis of their total energy consumption and agro-energetics ratio. The analysis of the energy parameters of the technology of field and meadow forage production showed that the energy cost of cultivation of grain and legume-grain agrocenoses and their structure varied significantly and depended on the composition of cenoses, different types and doses of fertilizers, the type and quantity of seeds of annual crops and their energy consumption. On average, over the years of research, energy consumption varied from 4.6 to 21.5 GJ/ha. The greatest energy costs had a single-species sowing of common oats. At the same time, operational costs amounted to almost 4 GJ/ha or 17.9% of all costs (table 1).

Due to the need for the annual purchase of seeds and application of nitrogen fertilizers for oats, the embodied costs exceeded the operational costs by 4.5 times and amounted to 17.5 GJ/ha. Oat-and-tare mixtures sown in different ratios and in different ways, required for their green forage cultivation about 15 GJ/ha. The embodied costs accounted for only 11 GJ/ha, which corresponds to 74.2 % of all costs (figure 1).
Table 1. Structure of the total energy according to the energy consumption items in the cultivation of field and meadow agrocenoses, %.

| Energy consumption items       | Field agrocenosis | Meadow agrocenosis |
|--------------------------------|-------------------|--------------------|
|                                | Oats              | Oats + tare        |
| Agricultural machinery         | 4.8               | 1.0                |
| Labor resources                | 0.7               | 0.2                |
| Direct costs                   | 12.4              | 2.6                |
| Total operational energy costs | 17.9              | 25.8               |
| Seeds                          | 31.4              | 8.0                |
| Mineral fertilizers            | 50.6              | 3.1                |
| Total embodied energy costs    | 82.1              | 74.2               |
| Total aggregate energy         | 100               | 100                |

Figure 1. Ratio of embodied and operational energy consumption in the cultivation of field and meadow agrocenoses

Unlike one-year agrocenoses, perennial grasses do not require the annual purchase of seeds, so the embodied costs for their cultivation are much lower.

In our experiments, the cultivation of grain grass beginning from the 2nd year of life with a single-cut mode of mowing required only 14 GJ/ha of total energy. Besides, the embodied costs accounted for 11 GJ/ha, that is 78% of all costs. In the cultivation of legume-grain grass stands, energy
consumption decreased and amounted to 4.6 GJ/ha, of which the embodied costs accounted for 3.1 GJ/ha or 67.1% of all costs.

The introduction of the legume component that does not require the application of energy-intensive nitrogen fertilizers in the field and meadow agrocenoses significantly reduced the energy consumption for their cultivation. Thus, in the field cenosis through the sowing of Vicia saliva (tare), the cost of energy has decreased by almost 1.5 times and amounted to 15 GJ/ha. Introduction of clover in the meadow agrogenoses has led to more effective cost reduction – almost 3 times. The energy consumption was only 6.2 GJ/ha.

In all agrogenoses, the operational energy costs were not equally distributed. The lowest cost accounted for labor resources (10 to 30%), and the highest costs (60 to 70%) – for fuel.

The calculation of the agroenergetics ratio of cultivation of field and meadow agrogenoses showed that all technologies were effective. The energy efficiency ratio varied from 1.9 to 8.7 (table 2).

| Indicators                          | Field agrogenosis | Meadow agrogenosis |
|------------------------------------|-------------------|--------------------|
|                                    | Oats              | Oats + tare        | Grain grass stand | Legume – grain grass stand |
| Herbage obtained, ton / ha         | 17.8              | 22.0               | 21.4              | 19.7                       |
| Exchange energy in 1 ton of forage, GJ | 2.3               | 1.58               | 2.72              | 2.02                       |
| Exchange energy accumulation, GJ / ha | 40.9              | 34.8               | 58.2              | 39.8                       |
| Total energy costs, GJ/ha          | 21.5              | 15.0               | 14.0              | 4.6                        |
| Agroenergetics ratio               | 1.9               | 2.3                | 4.2               | 8.7                        |

The total energy consumption has had a significant impact on the energy efficiency ratio. The lowest energy consumption in the cultivation of legume-grain agrogenoses resulted in a higher coefficient compared to grains. Due to the inclusion of Vicia saliva (tare) in the field cenosis, the agroenergetics ratio increased by 21%, that is, the energy yield exceeded its costs by 2.3 times. Cultivation of meadow clover in meadow grass stands contributed to an increase in energy efficiency by 2 times. At the same time, the yield of exchange energy was almost 9 times higher than the energy spent on the cultivation of meadow legume-grain agrogenosis. That is, the introduction of the legume component in the field and meadow agrogenoses will not only increase the nutritional value of the forage, but also increase the agroenergetics ratio.

4. Conclusion

The analysis of the energy parameters of the technology of field and meadow forage production showed that the energy cost of cultivation of grain and legume-grain agrogenoses and their structure varied significantly and depended on the composition of cenoses, different types and doses of fertilizers, the type and quantity of seeds of annual crops and their energy consumption. The introduction of the legume component that does not require the application of energy-intensive nitrogen fertilizers in the field and meadow agrogenoses and significantly reduces the energy consumption for their cultivation by 1.5–3 times. That is, the introduction of the legume component in the field and meadow agrogenoses will not only increase the nutritional value of the forage, but also increase the agroenergetics ratio.

In addition, perennial meadow grass stands do not require the annual purchase of seeds, so the embodied costs for their cultivation are significantly lower compared to annual field agrogenoses. For the purpose of resource saving in forage production it is expedient to cultivate legume-grain agrogenoses. The accumulation of exchange energy covers the energy spent on the cultivation of field cenoses by 2.3 times, and in the cultivation of meadow grass stands – almost by 9 times.
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