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RESEARCH ARTICLE

Economic and energy efficiency of growing legume grasses

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Abstract

Modern requirements of agriculture stand in need of new approaches to provide the region with high-quality fodders and develop new methods of their production. Therefore, solving the problem of providing animals with cheap full value grass fodder, the production of which is based on modern technologies with taking into account existing trends of climatic change, and in our region, is undoubtedly relevant. Calculations of economic and energy efficiency showed that cultivation of perennial legume grasses without application of mineral fertilizers under conditions of Precarpathians provided net profit of 11.1-15.8 thousand UAH/ha, profitability level of 160%-183%, prime cost per 1 ton of fodder units 1.7-1.9 thousand UAH- cost, 2.8-3.3 recoupment of energy costs by the outcome of exchange energy per 1 ha (BEC) and output of gross energy (CEE) 6.4-7.6 at energy costs per 1t of fodder units 3.6-4.3 GJ. Among the types of perennial legume grasses on all backgrounds of fertilizers on average for the first three years of grasslands use the best indices of economic and energy efficiency were obtained when growing *Lotus corniculatus*, and the worst-*Medicago sativa*. Other studied species, namely *Trifolium pratense* and *Trifolium hybridum*, occupied an intermediate place by these indices. Among fertilizer variants, the best indices of economic efficiency are provided by the application of mineral fertilizers at a dose of $P_{60}K_{60}$.

Keywords: Legume grasses, *Bromus inermis*, fertilization, profitability, energy efficiency, costs

Introduction

Under current conditions of economic downturn for successful development of agriculture in Ukraine, it is required the development of energy– and resource-saving technologies based on the use of perennial grass potential, in particular legume grasses, as a source of natural nitrogen. Today, have been developed the methods which make it possible to determine the energy and economic efficiency of fodder production and will allow recommending technologies with optimal values of these indices. Only calculation of economic and energy efficiency is the reason for the introduction of the technology into production (Konyk 2016).

There are almost 8.5 million hectares of natural fodder lands in Ukraine, including 4.6 million hectares of pastures and 3.1–3.3 million hectares of hayfields. Modern meadows have a huge impact on sustainable development and economic activity in the agricultural sector (Kanianska et al. 2006; Strijker 2005). They play an important role in strengthening livestock fodder base, as they provide a significant share of the need in fodders for farm ruminants both in the form of green fodder from pastures and hay from hayfields and in the form of silage and haylage (Finneran et al. 2012; Huyghe et. et al. 2014; Oenema et al. 2014; Karbivska et al. 2022). Grasslands are a major component of landscapes and they are increasingly valued for their important role in ensuring sustainable development of ecosystems and generating an overall positive impact on the environment (Huyghe et al. 2014; Isselstein, 2014; Hlushchenko 2008; Paz-Ferreiro 2016; Ates et al. 2017; Litvinov et al. 2020).

In solving the problem of stopping the decline and increasing livestock production, the leading role belongs to fodders the cost of which takes the largest share in the prime cost of livestock products (Klymenko 2009; Karbivska et al. 2020a; Karpenko et al. 2019). Meadow grasses provide the cheapest fodder, and hence the cheapest livestock products (Veklenko 2003; Scherner et al. 2016).

The main index of economic efficiency of newly created meadow agro phytocoenoses is the cost of creating grassland, as they take the main share of all costs (Biermacher 2012). The use of legumes and cereal grasses is economically profitable only with a high proportion of legume grasses, and as it is known, they CEEp high level for only 2-3 years (Vyhovskyi 2013; Pukalo 2015; Panakhyd et al. 2020). One of the most important factors influencing the efficiency of growing meadow grasses is mineral fertilization (Schellberg 1999; Konyk 2016; Demydas et al. 2021).

Recently, due to the price rise of non-renewable energy sources in Ukraine, there has been a trend towards wider introduction of energy and resource-saving technologies, non-traditional and constantly renewable energy sources that reduce energy consumption for the production of certain fodder kinds (Konyk 2016; Karbivska et al. 2020; Kvitko et al. 2021; Tonkha et al. 2021). Determination of both consumed and received energy makes it possible to quantify the energy efficiency of fodder crop growing (Tatariko 2005; Hetman 2014; Karbivska et al. 2020b). In meadow growing, energy assessment of technologies is estimated by recoupment of total energy costs by output from 1 ha of gross or exchange energy in GJ, which, according to Kurgak (2010), during the improvement of natural fodder lands in Polissia ranged from 3.0 to 6.0 and 1.5–3.0.

In recent years, due to significant price rise in energy sources, mineral fertilizers and fuel the costs of fertilization, mowing usage and the production of grass fodder, in general, have also risen. An important factor in reducing fodder prime cost is the use of perennial grasses (Voloshyn 2018; Litvinov et al. 2019; Ryan 2017; Hryhoriv et al. 2021; Karbivska et al. 2021).

It should be noted that the economic and energy efficiency of growing legume grasses on sod-podzolic soil is insufficiently studied. This emphasizes the relevance of research and the need to substantiate these processes in the conditions of Precarpathians of Ukraine. That is why indicated issues were the purpose of research, the results of which are presented in this article.

Materials and Methods

The research was conducted at the stationary polygon of Agro-chemistry and Soil Science Department, established in 2010, and the use with relevant records and observations was carried out during 2011–2013 according to generally accepted methodology. The soil cover of the experimental field is represented by sod-podzolic surface-gleyed soil.

Interaction of two factors was studied in the experiment: A-grass species and seeding rates; B-fertilization: without fertilizers, $P_{60}K_{60}$, $P_{90}K_{90}$, and for Bromus inermis without fertilizers, $P_{60}K_{60}$, $N_{60}P_{60}K_{60}$ (Tab. 1). Mineral fertilizers were applied superficially in the form of ammonium nitrate (34% a.s.), granular superphosphate (19% a.s.) and potassium–magnesium (29% a.s) in early spring.

Table 1. The scheme of the experiment.

Factor A-grass species and seeding rates, kg/ha	Factor B-fertilization
Trifolium pretense, 18 *Medicago sativa*, 18 *Trifolium hybridum*, 14 *Lotus corniculatus*, 12	without fertilizers $P_{60}K_{60}$ $P_{90}K_{9}$
Bromus inermis, 25 (cereal grassland)	without fertilizers $P_{60}K_{60}$ $N_{90}P_{90}K_{9}$

The size of sown areas-10 m², accounting-8 m². The experiment was repeated four times. Zonal and promising varieties of legume and cereal grasses were sown: Trifolium pratense–Darunok, Trifolium hybridum–Rozheva 27, Lotus corniculatus–Ajax, Medicago sativa–Andy, Bromus inermis–Mars.

Evaluation of weather conditions in the years of research was carried out based on meteorological data obtained at Ivano-Frankivsk Regional Center for Hydrometeorology. Weather conditions in 2011 were different from long-term indices but favourable for the formation of agro phytocoenoses of legume grasses. During the growing season, precipitations fell by 13.1 mm less than normal, while the average daily air temperature decreased by 4.5°C compared to long-term averages.

The year 2012 was characterized by high temperatures with the average daily air temperature exceeding the long-term norm by +1.5°C and insufficient precipitations when they fell by 23.7% less than the norm. Weather conditions in 2013 differed from the average long-term data but were quite favourable for the formation of agro phytocoenosis of legume grasses. The growth and development of plants were satisfactory.

An economic evaluation of perennial grass cultivation technologies taking into account the studied elements was carried out according to the method of evaluation of scientific research effectiveness using technological maps with the prices of 2020, energy evaluation–according to the method of Medvedovskyi and Ivanenko (Medvedovskyi 1988).

Results and Discussion

On average, over the years of using a more influential factor in the yield of 1 ha of dry matter was factor A with a share of 63%. The share of factor B was 37%. It should be noted that in the first year of using herbs, the share of factor A was the highest 61%. Later, due to a decrease in the amount of legume component and a certain decrease in the action of symbiotic nitrogen, it decreased, reaching the level of 54% in the third year and vice versa, the impact of factor B increased from 39% to 46% over the years (Karbivska et al. 2019).

It was found that the productivity of perennial legume grasses on average over the years of study for dual-use invariants without fertilizers and for the application of $P_{60}K_{60}$ ranged from 5.03 t/ha to 6.47 t/ha of dry weight, 3.62 t/ha to 4.98 t/ha of fodder units, 0.79 t/ha-1.08 t/ha of crude protein, 43.3 t/ha-58.2 GJ/ha of metabolic energy.

Among the studied species of perennial legume grasses, the highest productivity was provided by Trifolium pratense and Lotus corniculatus, which dominate Medicago sativa and Trifolium hybridum by 19%-31%.

Indices of economic efficiency while growing different types of perennial legume grasses in single-species crops were 20%-25% lower than economic efficiency indices of growing mixtures of perennial legume grasses.

In the variant without fertilizers, the best indices of economic efficiency were recorded, in particular, net profit and profitability level ranged from 11142–15804 UAH/ha and 160%–183% with the lowest prime cost of 1 ton of fodder units (1768–1922 UAH) and 1ton of crude protein (UAH 8080-8940) (Tab. 2). Cereal grassland provided lower net profit and profitability by 1.5–2.1 and 1.2–1.3 times respectively, and the prime cost of 1 ton of fodder units and crude protein–higher by 1.1–1.3 and 1.6–1.7 times.

As a result of increasing doses of phosphorus and potassium fertilizers, economic efficiency indices of growing perennial legume grasses in single-species crops decreased. In particular, with the application of $P_{90}K_{90}$ compared to the variant without fertilizers on legume grasslands, net profit and profitability decreased by 1.3–1.4 and 2.2–2.6 times respectively, the prime cost of 1 ton of fodder units and crude protein increased by 1.5–1.6 times.

At the same time, with the application of $P_{90}K_{90}$ net profit and profitability compared to the variant without fertilizers decreased even more-respectively by 1.7–1.8 and

Table 2. Economic efficiency of growing legume grasses depending on fertilizers on sod–podzolic soil, the average for 2011-2013.

Grass species and seeding rates, kg/ha	Gross production, UAH/ha	Costs, UAH/ha	Net profit, UAH/ha	Prime cost of 1 t, UAH		Profitability, %
				Fodder units	Crude protein	
Without fertilizers (control)						
Trifolium pratense, 18	22750	8235	14515	1810	8153	176
Medicago sativa, 18	18100	6958	11142	1922	8808	160
Trifolium hybridum, 14	w18900	7152	11748	1892	8940	164
Lotus corniculatus, 12	24450	8646	15804	1768	8080	183
Bromus inermis, 25	13100	5490	7610	2095	14076	139
$P_{60}K_{60}$						
Trifolium pratense, 18	23050	12775	10275	2771	11939	80
Medicago sativa, 18	18500	11498	7002	3108	14022	61
Trifolium hybridum, 14	19950	11692	8258	2930	13919	71
Lotus corniculatus, 12	24900	13186	11714	2648	12209	89
Bromus inermis, 25	13850	9930	3920	3585	23643	39
$P_{90}K_{90}$						
Trifolium pratense, 18	23850	14978	8872	3140	13998	59
Medicago sativa, 18	19000	13701	5299	3606	16709	39
Trifolium hybridum, 14	20050	13895	6155	3465	16741	44
Lotus corniculatus, 12	25600	15389	10211	3006	13990	66
$N_{60}P_{60}K_{60}$						
Bromus inermis, 25	19900	12103	7797	3041	15925	64

Table 3. Energy efficiency of growing legume grasses under conditions of different fertilization, average for 2011-2013

Grass species and seeding rates, kg/ha	Energy costs, GJ/ha	CEE	BEC	Energy costs per 1 ton of fodder. un., GJ
	Without fertilizers (control)			
Trifolium pratense, 18	17.1	7.4	3.2	3.8
Medicago sativa, 18	15.4	6.4	2.8	4.3
Trifolium hybridum, 14	15.7	6.7	2.9	4.2
Lotus corniculatus, 12	17.5	7.6	3.3	3.6
Bromus inermis, 25	13.6	4.8	2.3	5.2
	$P_{60}K_{60}$			
Trifolium pratense, 18	21.5	6.0	2.6	4.7
Medicago sativa, 18	19.8	5.3	2.3	5.4
Trifolium hybridum, 14	20.1	5.5	2.4	5.0
Lotus corniculatus, 12	21.9	6.2	2.7	4.4
Bromus inermis, 25	18.1	3.8	1.8	6.5
	$P_{90}K_{90}$			
Trifolium pratense, 18	23.9	5.5	2.4	5.0
Medicago sativa, 18	21.9	4.6	2.0	5.8
Trifolium hybridum, 14	22.4	4.8	2.1	5.6
Lotus corniculatus, 12	24.0	5.5	2.4	4.7
	$N_{60}P_{60}K_{60}$			
Bromus inermis, 25	22.4	4.2	2.0	5.6

2.8–4.1 times, and the prime cost of 1 ton of fodder units and crude protein increased by 1.7–1.9 times. A decrease of economic efficiency indices with the application of phosphorus and potassium fertilizers is stipulated by a significant increase of their application cost with an insufficient increase in the value of gross output.

The lowest indices of economic efficiency were obtained on cereal grassland with the application of $P_{60}K_{60}$, with a net profit of 3920 UAH/ha and profitability of 39%, which is by 1.9-3.6 times less, and the cost of 1 ton of fodder units and crude protein 3585 and 23643 UAH, which is by 1.7 times more than the control. Adding nitrogen in a dose of N_{60} to $P_{60}K_{60}$ at cereal grassland provided net profit per 1 ha the level of 7797 UAH, which was 187 UAH higher than the level achieved in the version without fertilizers.

Among the species of perennial legume grasses, on average for the first three years of grassland use, the best indices of economic efficiency were obtained for the cultivation of Lotus corniculatus, and the lowest–for the cultivation of Medicago sativa. The rest of the studied species occupied an intermediate place.

Economic efficiency indices are unstable–they are influenced by inflation processes, price parity for industrial and agricultural products, the level of wages in agriculture, government subsidies for material and technical resources and so on. Therefore, they do not always objectively characterize the results of economic activity. As a result, a much more objective assessment of land use efficiency and technological operations in the cultivation of crops, and our case–legume grasses, is provided by energy indices expressed in calories, joules, the value of which is not affected by changing market environment.

The efficiency of energy resources primarily depends on soil and climatic conditions that are different amounts of energy are consumed for producing a unit of production in different regions. In the conducted studies, energy efficiency indices depended on the type of grass and fertilizers (Tab. 3).

In the variant without fertilizers, recoupment of energy costs from 1 ha of exchange and gross energy as BEC and CEE under conditions of growing legume grasses in comparison with cereal grasses increased from 2.3 to 2.8–3.3 respectively, and energy costs per 1 ton of fodder units, in this case, decreased by 0.9–1.6 MJ. On the background of application $P_{60}K_{60}$ the index BEC increased from 1.8 to 2.3–2.7 or 0.5–0.9, the index CEE–from 3.8 to 5.3–6.2 or by 1.5–2.4, and energy consumption per 1 ton of fodder units decreased from 6.5 to 4.4–5.4 or by 1.1–2.1 GJ.

Analysis of fertilizer variants showed that indices of energy efficiency decreased with increasing doses of phosphorus and potassium fertilizers in the process of growing perennial grasses. The highest total energy consumption per 1 ha and energy consumption per 1 ton of fodder units during cultivation of perennial legume grasses (respectively 21.9–24.0 and 4.7–5.8 GJ) was observed on the background of $P_{90}K_{90}$, which is 1.1 times more compared to the background $P_{60}K_{60}$ and 1.3–1.4 times compared to the variant without fertilizers.

On the contrary, recoupment of the total energy consumption per 1 ha of exchange (BEC) and gross (CEE) energy for growing legume grasses on the background of P90K90 was the lowest with the rates of 2.0–2.4 and

4.6–5.5 respectively, which is 0.2–0.7 less compared to the background $P_{60}K_{60}$ and 0.8–2.1 less than the control. On cereal grassland, the highest total energy consumption per 1 ha (22.4 GJ) was observed on application background of $N_{60}P_{60}K_{60}$, which is 1.2 times more compared to the background of $P_{60}K_{60}$ and 1.6 times more than in the variant without fertilizers. At the same time, energy consumption per 1 ton of fodder units was the highest (6.5 GJ) on application background of $P_{60}K_{60}$, which is 1.2 times higher compared to $N_{60}P_{60}K_{60}$ and 1.3 times higher than in the variant without fertilizers.

Conclusions

Cultivation of perennial legume grasses without mineral fertilizers under conditions of Precarpathians provides 11.1–15.8 thousand UAH/ha of net profit; 160%–183%–profitability level; 1.7-1.9 thousand UAH–prime cost of 1 ton of fodder units; 2.8–3.7 recoupment of total energy costs by the output from 1 ha of exchange energy and 6.4–7.6 gross energy; 3.6–4.3 GJ–energy consumption per 1 ton of fodder units. On sod–podzolic soil, for three years of use, the best indices of economic and energy efficiency are provided by growing Lotus corniculatus in single-species crops.

The results obtained in this research provide valuable information concerning the economic and energy efficiency of growing legume grasses and Bromus inermis. However, further research is needed for verifying the results of the study and further improvement of cultivation technology, reduction of fertilizer cost, as well as the increase of agro phytocoenoses productivity. This has to help increase the economic and energy efficiency of legume agro phytocoenoses in the future.

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