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RESEARCH ARTICLE

Economic and energy efficiency of growing Cereal grasses

U.M. Karbivska[1], N.V. Kolodnenko[2*], N.M. Asanishvili[3], I.M. Malinovskaya[3], A.V. Holodna[3], H.S. Konyk[4], H.Ya. Panakhyd[4], A. H. Dzyubailo[5], H.M. Solovei[6], N.Ya. Hetman[7], M.D. Voloshchuk[1], Ya.Ya. Hryhoriv[1], O.Yu. Turak[1], O.D. Turak[1]

[1]Vasyl Stefanyk Precarpathians National University, 57 Shevchenko Street, Ivano-Frankivsk, 7601841, Ukraine
[2]Sumy National Agrarian University, Gerasim Kondratyev Str. 160, 40021, Sumy, Ukraine; * andb201727@ukr.net
[3]National Scientific Centre "Institute of Agriculture of the National Academy of Agrarian Science of Ukraine", Mashynobudivnykiv Str. 2b, 08162, Chabany, Ukraine
[4]Institute of Agriculture of the Carpathian Region NAAS, 5 Hrushevskoho Street, p. Obroshino, Lviv region, 81115, Ukraine
[5]Drohobych State Pedagogical University named after Ivan Franko, Drohobych, Lviv region,82100, Ukraine
[6]National Scientific Agricultural Library of NAAS, 03127, Kyiv, Ukraine
[7]Vinnytsia National Agrarian University, street Sunny, 2, 21008, Vinnytsia, Ukraine

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Abstract

Modern requirements of agriculture require new approaches to provide the region with high quality feed and develop new methods of their production. Therefore, solving the problem of providing animals with cheap complete grass fodder, the production of which is based on modern technologies, taking into account the existing trends of climate change, is undoubtedly relevant in this region.

Economic and energy efficiency of growing cereal grasses depending on fertilization has been studied. On the basis of obtained results it has been found that cultivation of perennial grasses without application of mineral fertilizers under conditions of Precarpathians provides 5.9-7.8 thousand UAH/ha of net profit, 116%-139% the level of profitability, 2.1-2.3 thousand UAH-prime cost of 1 ton of fodder units, 2.8-3.7 BEC and 4.2-4.8 CEE, 2.1-3.3 GJ energy consumption per 1 ton of fodder units. Among the species of perennial grasses on all fertilizer backgrounds, on average for the first three years of using grasses the best indices of economic and energy efficiency were obtained when growing *Lolium perenne*, and the lowest *Festuca rubra*. Other studied species, namely *Dactylis glomerate*, *Festuca orientalis*, *Bromus inermis*, *Phalaris arundinacea*, and *Phléum praténse* occupied an intermediate place by these indices. Among fertilizer variants, the best indices of economic efficiency are provided by full application of mineral fertilizers in a dose of $N_{90}P_{60}K_{60}$.

Keywords: Cereal grasses, fertilization, profitability, energy efficiency, costs

Introduction

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

Among fodder crops grown in our area, perennial grasses play an important role. They are undemanding to living conditions. Thanks to a well-developed root system they absorb nutrients and soil moisture reserves more efficiently than other crops. Growing of perennial grasses in one place during several years does not require significant annual material and production costs related to soil preparation, sowing, application of pesticides. Due to relatively low cost and ability to give several mowings during the year, perennial grasses are the basis for uninterrupted fodder supply for animals in summer and significant reserve of high-quality cheap haylage and hay for cattle wintering (Hlushchenko 2008; Paz-Ferreiro 2016; Ates et al. 2017; Litvinov et al. 2020).

The main indicator of economic efficiency of meadow agrophytocenoses is the cost of their creation, which is significant, and is main part of all costs (Vyhovskyi 2013; Pukalo 2015).

One of the most important factors influencing efficiency of growing meadow grasses is mineral fertilization. Thus, with application of phosphorus and potassium fertilizers because of low yielding capacity of meadow grasses, the cost of production increases, and with application of complete mineral fertilizers increases the cost of growing a unit of production and decreases profitability. Irish scientists relate this fact to rapid rise of prices for mineral fertilizers and relative rise of prices for agricultural products (Schellberg et al. 1999; Konyk 2016; Demydas et al. 2021).

In recent years, in the world practice, along with traditional methods of assessing crop production efficiency using monetary and labor indices, becomes more and more important the method of energy assessment, which takes into account both amount of energy spent on agricultural production and amount of energy accumulated in it. Energy assessment makes it possible to compare different technologies of agricultural production in terms of energy consumption, determine the structure of energy flows in agrocenoses and identify main reserves of saving technical energy in agriculture. Determination of both consumed and received energy makes it possible to quantify energy efficiency of growing fodder crops (Tatariko et al. 2005; Hetman et al. 2014; Karbivska et al. 2020).

Energy analysis of technologies in fodder production and meadow cultivation is important, as the energy contained in fodders has two functions: ensuring livelihood of animals and production of livestock products. This analysis makes it possible to determine not only recoupment of energy costs for production of certain types of grass fodders, but also to define energy intensity of fodder unit. Recently, because of price rise for non-renewable energy sources, in Ukraine there appeared a tendency to wider implementation of energy and resource-saving technologies, non-traditional and constantly renewable energy sources which reduce energy consumption for production of certain types of fodders (Konyk 2016; Karbivska et al. 2020; Kvitko et al. 2021; Tonkha et al. 2021).

It is known that in meadow cultivation energy assessment of technologies is conducted by recoupment of total energy costs by output of gross or exchange energy from 1 ha in GJ, which, according to Kurgak (2010), during improvement of natural fodder lands of Polissia ranged within 3.0-6.0 and 1.5-3.0.

In recent years, due to significant price rise of energy, fertilizers and fuels, has risen the cost of fertilization, mowing use and fodder production in general. An important factor in reducing fodder cost price is the use of perennial grasses, which are cheap source of fodder (Voloshyn 2018; Litvinov et al. 2019; Ryan 2017; Hryhoriv et al. 2021). It should be noted that the economic and energy efficiency of growing cereals on sod-podzolic soil has not been studied enough. This emphasizes the relevance of research and the need to substantiate these processes in the Carpathians of Ukraine. Therefore, these 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 experimental field of Agrochemistry and Soil Science Department, laid in 2011 according to generally accepted methodology. The soil cover of experimental field is represented by sod-podzolic surface-clayed soil.

Repetition-three times, accounting area of experimental plot-25 m^2. Zonal and promising varieties of cereal grasses were sown: Phléum praténse-Carpathian, *Lolium perenne*-Kolomyiskaa, *Festuca orientalis*-Menchulska, *Dactylis glomerate*-Stanislavska, *Festuca rubra*-Hoverla, *Phalaris arundinacea*-Smerichka.

Interaction of two factors was studied in the experiment (Tab. 1): A–grass species by level of ripeness; B-fertilization: without fertilizers, $P_{60}K_{60}$, $N_{90}P_{60}K_{60}$, where mineral fertilizers were used: ammonium nitrate (34% a.s.); potassium and magnesium sulphate (29% a.s.); superphosphate (19% a.s.).

Table 1. The scheme of the experiment.

Factor A-grass species by level of ripeness	Factor B-Fertilization
1. *Phléum praténse*	Without fertilizers
2. *Lolium perenne*	
3. *Festuca orientalis*	$P_{60}K_{60}$
4. *Bromus inermis*	
5. *Dactylis glomerate*	
6. *Festuca rubra*	$N_{90}P_{60}K_{60}$
7. *Phalaris arundinacea*	

Evaluation of weather conditions in research years was carried out on the basis of meteorological data obtained at Ivano-Frankivsk Regional Center for Hydrometeorology. During vegetation period of 2011, precipitation was by 13.1 mm smaller than the norm, while average daily air temperature decreased by 4.5°C compared to long-term average indices, 2012 was characterized by increased temperature regime, with average daily air temperature by +1.5°C exceeding long-term norm, and insufficient precipitation, when precipitation was by 23.7% smaller than the norm.

Weather conditions of 2013 differed from average long-term data, but they were quite favorable for the formation of cereal grass agrophytocenosis. The growth and development of plants was satisfactory.

Economic evaluation of perennial grass growing technologies, with taking into consideration the studied elements, was performed according to evaluation methodology of scientific research efficiency using technological maps with prices of 2020, energy evaluation-according to the method of Medvedovsky and Ivanenko (Medvedovskyi 1988).

Results

In the process of growing these types of perennial grasses in single-species sowings in the variant without fertilizers, the net profit and profitability level ranged from 5112 UAH/ha-5593 UAH/ha (hryvnia per hectare) and 116%-139%, respectively, with the lowest prime cost of 1 ton of fodder units (2095-2313 UAH) and mainly with the lowest prime cost of 1 ton of crude protein (UAH 13317–15491) (Tab. 2).

The lowest indices of economic efficiency were on the background of $P_{60}K_{60}$, with net profit of 2377 UAH/ha-3920 UAH/ha and profitability of 25%-39%, which is less by 2.0-2.4 and 3.6-4.6 times respectively than in the control and with prime cost of 1 tons of fodder units and crude protein respectively 3595 UAH-3989 UAH and 22289 UAH-26036 UAH, which is by 1.7 times more compared to the variant without fertilizers. The highest net profit per 1 ha for growing all species of cereal grasses was with addition of nitrogen in a dose of N_{90} to $P_{60}K_{60}$ and reached 6527 UAH–10670 UAH.

The level of profitability and prime cost of 1 ton of fodder units in this case occupied an intermediate place between the variant without fertilizers and the variant withe application of $P_{60}K_{60}$, and prime cost of 1 ton of crude protein was equal to the variant without fertilizer.

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

Grass species and norms of seed sowing, kg/ha	Fertilization	Gross production, UAH/ha	Costs, UAH/ha	Net profit, UAH/ha	Profitability, %	Prime cost 1 t, UAH	
						Fodder units	Crude protein
Early-ripening grasses							
Dactylis glomerate, 16	without fertilizers (control)	11800	5242	6558	125	2221	14168
	$P_{60}K_{60}$	12300	9503	2797	29	3863	24367
	$N_{90}P_{60}K_{60}$	22100	12903	9197	71	2919	13441
Middle-ripening grasses							
Festuca orientalis, 26	without fertilizers (control)	12150	5350	6800	127	2202	14459
	$P_{60}K_{60}$	12650	9630	3020	31	3806	24692
	$N_{90}P_{60}K_{60}$	23100	13030	10070	77	2820	13296
Lolium perenne, 26	without fertilizers (control)	13350	5593	7757	139	2095	13317
	$P_{60}K_{60}$	13950	10030	3920	39	3595	22289
	$N_{90}P_{60}K_{60}$	24100	13430	10670	79	2786	12913
Bromus inermis, 26	without fertilizers (control)	12350	5395	6955	129	2184	14197
	$P_{60}K_{60}$	13050	9733	3317	34	3729	24333
	$N_{90}P_{60}K_{60}$	22450	13133	9317	71	2925	13971
Festuca rubra, 18	without fertilizers (control)	11050	5112	5938	116	2313	15491
	$P_{60}K_{60}$	11750	9373	2377	25	3989	26036
	$N_{90}P_{60}K_{60}$	19300	12773	6527	51	3309	16168
Phalaris arundinacea, 14	without fertilizers (control)	12050	5330	6720	126	2221	14806
	$P_{60}K_{60}$	12500	9780	2720	28	3912	25737
	$N_{90}P_{60}K_{60}$	21600	13180	8420	63	3051	14326
Late-ripening grasses							
Phléum praténse, 14	without fertilizers (control)	11950	5302	6648	125	2218	14330
	$P_{60}K_{60}$	12500	9590	2910	30	3791	24590
	$N_{90}P_{60}K_{60}$	21600	12990	8700	67	3272	15841

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

Grass species and sowing rates, kg/ha	Fertilization	Energy consumption, GJ/ha	CEE	BEC	Energy consumption per 1 t of fodder units, GJ
Early-ripening grasses					
Dactylis glomerate, 16	without fertilizers (control)	13.0	4.4	2.1	5.51
	$P_{60}K_{60}$	18.4	3.2	1.5	7.48
	$N_{90}P_{60}K_{60}$	27.6	3.8	1.8	6.24
Middle-ripening grasses					
Festuca orientalis, 26	without fertilizers (control)	13.1	4.4	2.1	5.39
	$P_{60}K_{60}$	18.6	3.4	1.6	7.35
	$N_{90}P_{60}K_{60}$	28.1	4.0	1.9	6.08
Lolium perenne, 26	without fertilizers (control)	13.5	4.8	2.3	5.06
	$P_{60}K_{60}$	19.4	3.4	1.6	6.95
	$N_{90}P_{60}K_{60}$	29.0	4.0	1.9	6.02
Bromus inermis, 26	without fertilizers (control)	13.2	4.6	2.2	5.34
	$P_{60}K_{60}$	18.9	3.4	1.6	7.24
	$N_{90}P_{60}K_{60}$	28.1	3.8	1.8	6.26
Festuca rubra, 18	without fertilizers (control)	12.8	4.2	2.0	5.79
	$P_{60}K_{60}$	18.1	3.2	1.5	7.70
	$N_{90}P_{60}K_{60}$	26.6	3.6	1.7	6.89
Phalaris arundinacea, 14	without fertilizers (control)	13.1	4.4	2.1	5.44
	$P_{60}K_{60}$	18.6	3.4	1.6	7.44
	$N_{90}P_{60}K_{60}$	27.8	3.8	1.8	6.44
Late-ripening grasses					
Phléum praténse, 14	without fertilizers (control)	13.1	4.4	2.1	5.48
	$P_{60}K_{60}$	18.6	3.4	1.6	7.35
	$N_{90}P_{60}K_{60}$	27.2	3.6	1.7	6.85

While growing perennial grasses in single-species sowings, the highest indices of energy efficiency were obtained in the variant without fertilizers. In particular, total energy consumption both per 1 ha and per 1 ton of fodder units was the lowest and ranged between 12.8 GJ-13.5 GJ and 5.06 GJ-5.79 GJ, respectively, and recoupment of energy consumption by the outcome of BEC (Bioenergy Coefficient) and CEE (Energy Efficiency Coefficient) exchange and gross energy as BEC and KEE from 1 ha was the largest with indices 2.0-2.3 and 4.2-4.8, respectively (Tab. 3).

Among the variants of fertilization, the lowest indices of energy efficiency were observed on the background of $P_{60}K_{60}$ with recoupment of energy consumption for BEC and CEE respectively 1.5-1.6 and 3.2-3.4, which is by 1.3-1.4 times less than in the control, and with total energy consumption per 1 ton of fodder units 6.95 GJ-7.70 GJ, which is 1.3-1.4 times more than in the variant without fertilizers. Among the species of perennial grasses on all fertilizer backgrounds, on average for the first three years of grassland use, the best indices of energy efficiency were obtained when growing *Lolium perenne*, and the worst when growing *Festuca rubra*.

Other studied species, namely *Dactylis glomerate, Festuca orientalis, Bromus inermis, Phalaris arundinacea, Phléum pratén*, occupied intermediate place in terms of energy efficiency.

Discussion

In growing perennial cereal grasses, among the nutrients of fertilizers, nitrogen is the most effective one. Comparing the variants without nitrogen and the variants with application of N_{90}, the net profit increased from 538 UAH/ha to 3270 UAH/ha, profitability from 26% to 46%, BEC from 0.2 to 0.6 and CEE from 0.1 to 0.2. On average for the first three years of grassland use when growing on sod-podzolic soil, the best indices of economic and energy efficiency are provided by *Lolium perenne*, and the worst-*Festuca rubra*.

Conclusion

The results obtained in this study provide valuable information on the economic and energy efficiency of growing cereals. However, further research is needed to verify the results of the study and further improve the technology of cultivation, reduce the cost of fertilizers, as well as increase the productivity of agrophytocenoses. This should help increase the economic and energy efficiency of cereals in the future.

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