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*RESEARCH ARTICLE*

# Economic and Energy Efficiency of Forming and Using Legume-Cereal Grass Stands Depending on Fertilizers

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The economic and energy efficiency of growing legume-cereal grass stands depending on fertilizers has been studied. The research results have revealed that cultivation of perennial legume-cereal grass stands without mineral fertilizers in the Carpathian region possesses the following features: the net profit totals 11.1-21.9 thousand UAH/ha, the level of profitability is 151-210%, the prime cost of 1 ton of feed units makes 1.6-2.0 thousand UAH, BEK is 2.8-3.7 GJ/ha, KEE is 6.4-8.5 GJ/ha, energy costs per 1 ton of feed units account for 3.1-4.3 GJ. Cultivation of bird's foot trefoil the companion sowings with cereals provides the highest indicators of economic and energy efficiency. Among the fertilizer options, the best cost-effectiveness options were with the application of phosphorus-potassium fertilizers at the rate of $P_{60}K_{60}$.

**Keywords:** Legumes And cereals; Efficiency; Grass stand; Fertilizers

## Introduction

The economic efficiency of growing meadow grasses largely depends on the species composition of the grass stand. The return on costs for growing cereal grass mixtures is the lowest, and with the inclusion of legumes in the grass mixtures, the profitability increases by 1.4-2.0 times, and the cost of 1 ton of feed units decreases by 1.6-1.8 times. Scientists of the NSC "Institute of Agriculture of the NAAS" argue that the enrichment of meadow cenoses with perennial leguminous herbs, compared with the use of nitrogen fertilizers on cereal grasses, can reduce expenditure and prime cost, increase the relative net profit and profitability by 2.5-6.5 times and payback by 40-120%. According to the studies conducted in Turkey, the introduction of birds-foot trefoil and sickle alfalfa in the grass mixtures can help to increase the share of relative net income by $ 83 as compared to cereals (Ates, 2017).

The main indicator of the cost-effectiveness of grassland agrophytocenoses is the cost of their formation, which is high and accounts for the bulk of all costs (Vyhovskyi, 2013; Pukalo, 2015).

Economic indicators are typically unstable. They are subjects to price fluctuations, market conditions, etc. For a more accurate assessment of technology, scientists have conducted an energy analysis that allows the evaluation of technology from an energy point of view in a single unit for all countries. Energy assessment combines the complex of energy costs for fertilizers and chemicals, electricity, fuel, etc., on the one hand, and the amount of energy received from the crop grown on the other hand. The results obtained in this case have stability over time, in contrast to the results of the calculation of economic efficiency, due to the lack of price stability for consumables and the cost of products obtained. In addition, the energy assessment of feeds and calculations of the costs of their production make it possible to determine the return on total energy (Konyk, 2016; Litvinov, 2019).

In the structure of energy expenditures for livestock production, energy costs of feed units amount for 50 to 80%, depending on the breed and fodder. Therefore, it is reasonable to use a criterion for assessing the energy balance along with the criterion of the economic evaluation of any technological process. The main objective of the energy analysis of feed production is to comply with the main principles that ensure the rational use of non-renewable and renewable energy. It is known that in meadow farming the energy assessment of technologies is estimated by the payback of the total energy consumption by output from 1 ha of gross or exchange energy in GJ, which, according to Kurgak, with the improvement of natural forage lands, ranges from 3.0-6.0 and 1.5-3.0. (Kurgak, 2010; Karbivska, 2019a).

One of the most important factors influencing the efficiency of cultivation of meadow grasses is a mineral fertilizer. It should be noted that the application of phosphorous and potassium fertilizers can help increase a low capacity of meadow grasses, yet it raises the cost of production. Complete mineral fertilizers being introduced, both the unit cost of crop production and the profitability increase, which, according to the Irish scientists, stems from the rapid rise in prices for mineral fertilizers and a relative increase in prices for agricultural products (Schellberg, 1999).

In solving the problem of minimizing the downturn and increasing the production of livestock products, much depends on fodder. The cost of feed accounts for the largest share in the cost of livestock production (Klymenko, 2009). Meadow grass stands give the cheapest feed, hence animal products get less costly. (Veklenko, 2003).

In recent years, a significant increase in the price of energy carriers and a rise in prices for mineral fertilizers and fuel triggered the cost increase of fertilizing and hay cropping and, consequently, the production of grass feeds in general. An important factor in reducing the cost of feed is the use of perennial leguminous herbs, which are a cheap source of symbiotic nitrogen (Voloshyn, 2018; Karbivska, 2019b).

## Materials and Methods

Field researches, aimed at studying legume-grass mixtures, were conducted on the experimental plot of the Vasyl Stefanyk Precarpathian National University during 2015-2018.

The soil cover of the experimental sites is represented by sod-podzol soil with surface gleying on the alluvial-dealluvial deposits. The reaction of soil solution is acid (pH - 4.6). The content of humus is 0-20 см-2.4%. On average, the tilth topsoil contains the following mobile forms of nutrients: alkaline hydrolyzed nitrogen is 68 mg/kg, mobile phosphorus (by Kirsanov) is equal to 78 mg/kg soil, mobile potassium (by Kirsanov) amounts to 60 mg/kg.

Assessment of weather conditions during the years of research was carried out on the basis of meteorological data obtained from the Ivano-Frankivsk Regional Hydrometeorological Center. In 2015, the weather conditions were different from long-term indicators and yet favourable for the formation of legume-cereal agrophytocenoses. During the growing season, the rainfall was by 86.9 mm below normal, and there was an increase in the average daily air temperature by 0.8°C as compared to the average multi-year indicators. A decrease in temperature regime with average daily temperature by 0.6°C below the long-term normal and increased rainfall by 18.9% above the normal were characteristic of the year 2016. In 2017 weather conditions were close to medium-term.

Analyzing the weather conditions of 2018, we can argue that the lack of precipitation was observed in April and September with 19.6 and 23 mm respectively, which is by 27.4 and 22.0 mm less than the long-term average. The scheme of the experiment included the following options: (Table 1).

**Table 1.** The scheme of the field experiment.

| Factor A - types of grasses and their seeding rates, kg/ha | Factor B - fertilizers |
|---|---|
| 1. Red clover, 10 + cereals (red fescue grass, 10 + awnless brome, 12 + italian ryegrass, 10) | 1. Without fertilizers |
| 2. Creeping alfalfa 10 + cereals (red fescue grass, 10 + awnless brome, 12 + italian ryegrass, 10) | 2. P60K60 |
| 3. Birds-foot trefoil, 6 + cereals (red fescue grass, 10 + awnless brome, 12 + italian ryegrass, 10) | 3. P90K90 |
| 4. Fodder galega, 20 +cereals (red fescue grass, 10 + awnless brome, 12 + italian ryegrass, 10) | 4. N60P60K60 |
| 5. Cereals (red fescue grass, 10 + awnless brome, 12 + italian ryegrass, 10) | |
| 6. Red clover , 10 + cereals (meadow brome, 10 + reed fescue, 12 + intermediate wheat grass 10) | |
| 7. Creeping alfalfa 10 + cereals (meadow brome, 10 + reed fescue, 12 + intermediate wheat grass 10) | |
| 8. Birds-foot trefoil, 6 + cereals (meadow brome, 10 + reed fescue, 12 + intermediate wheat grass 10) | |
| 9. Fodder galega, 20 +cereals (meadow brome, 10 + reed fescue, 12 + intermediate wheat grass 10) | |
| 10. Cereals (meadow brome, 10 + reed fescue, 12 + intermediate wheat grass 10) | |

The following legume and cereal grasses were sown: Red clover - Anitra, Creeping alfalfa - Syniukha, Birds-foot trefoil - Aiaks, Fodder galega - Branets, red fescue - Aira, awnless brome - Mars, Italian ryegrass - Obrii, reed fescue - Liudmila, meadow brome - Boian, intermediate wheatgrass - Khors. Institute of Feed Research and Agriculture of Podillia of NAAS of Ukraine is the originator of the above - mentioned sorts. Generally accepted methods were used within the scope of this research (Dospekhov, 1985, Babych, 1998).

## Results and Discussion

The analysis of calculations of the economic efficiency of growing legume-cereal grass stands on sod-podzolic soils of the Carpathian region showed that the inclusion of perennial bean grasses in cereals mixtures significantly improved economic efficiency indicators on average over the years of 2015-2018. Legume-cereal grass stands with cereals represented by red fescue, awnless brome, italian ryegrass on the background without fertilizers proved to have a net income and profitability with the highest rates ranged 12567-19000 UAH/ha and 195-210% with the lowest cost of 1 ton of feed units (1613-1693 UAH) and 1 ton of raw protein (7393-7669 UAH) (Table 2). At the same time and under the same conditions, cereal grass stands showed net income and profitability lower by 1.9-2.9 times and 1.4-1.5 times respectively, while the cost of 1 ton of feed units and crude protein was 1.2-1.3 times and 1.7-1.8 times higher respectively. Having demonstrated the top indicators of economic efficiency, legume-cereal grass stands on backgrounds without fertilizers had the net income and break-even level, fluctuating within the range of 1474-21865 UAH/ha and 193-209% respectively with the cost of 1 ton of feed units and 1 ton of raw protein 1621-1707 and 7456-7825 UAH respectively. Among phosphate and potash, regardless of a cereal component, the best indicators of economic efficiency in all agricultural backgrounds were obtained in binary mixtures of birds-foot trefoil with cereals, whereas creeping alfalfa-cereals mixtures did not perform well, which is due to the highest and lowest feed productivity respectively. Red clover and Fodder galega cereal mixtures by these indicators took an intermediate place. With increasing doses of phosphate and potash fertilizers, indicators of economic efficiency worsened. In particular, following the introduction of $P_{60}K_{60}$ as compared with the option without fertilizers on legume-cereal grass stands, the net profit and profitability decreased by 1.3-1.4 and 2.0-2.2 times respectively, and the cost of 1 ton of feed units and crude protein increased by 1.4-1.6 times. Whereas following the introduction of P90K90, the net profit and profitability decreased by 1.4-1.7 and 2.3-3.3 times, and the cost of 1 ton of feed units and crude protein increased by 1.6-2.1 times respectively.

**Table 2.** Economic efficiency of growing perennial legume-cereal grass stands on different fertilizer backgrounds (average over 2015-2018).

| Experiment option | Fertilizers | Gross product, UAH/ha | Direct costs, UAH/ha | Operating profit, UAH/ha | Cost price 1 t, UAH | | Level of profitability, % |
|---|---|---|---|---|---|---|---|
| | | | | | Feed units | Crude protein | |
| | Without fertilizers | 25950 | 8450 | 17500 | 1667 | 7393 | 207 |
| 1. | $P_{60}K_{60}$ | 26800 | 12990 | 13810 | 2424 | 10825 | 106 |
| | $P_{90}K_{90}$ | 26900 | 15160 | 11740 | 2818 | 12426 | 77 |
| | Without fertilizers | 19000 | 6433 | 12567 | 1693 | 7942 | 195 |
| 2. | $P_{60}K_{60}$ | 19400 | 10673 | 8727 | 3751 | 12706 | 82 |
| | $P_{90}K_{90}$ | 20050 | 12843 | 7207 | 3202 | 15109 | 56 |
| | Without fertilizers | 28050 | 9050 | 19000 | 1613 | 7669 | 210 |
| 3. | $P_{60}K_{60}$ | 28700 | 13690 | 15010 | 2385 | 14080 | 110 |
| | $P_{90}K_{90}$ | 28950 | 15860 | 13090 | 2739 | 13000 | 83 |
| | Without fertilizers | 26400 | 8800 | 17600 | 1666 | 7521 | 200 |
| 4. | $P_{60}K_{60}$ | 26700 | 13140 | 13560 | 2461 | 11231 | 103 |
| | $P_{90}K_{90}$ | 27550 | 19650 | 7900 | 3566 | 16512 | 40 |
| | Without fertilizers | 11450 | 4817 | 6633 | 2103 | 13763 | 138 |
| 5. | $P_{60}K_{60}$ | 12100 | 9157 | 2943 | 3784 | 25436 | 32 |
| | $N_{60}P_{60}K_{60}$ | 18550 | 11677 | 6873 | 3147 | 16446 | 74 |
| | Without fertilizers | 26450 | 8723 | 17827 | 1649 | 7456 | 204 |
| 6. | $P_{60}K_{60}$ | 26800 | 13250 | 13550 | 2522 | 11134 | 102 |
| | $P_{90}K_{90}$ | 27650 | 15463 | 12187 | 2796 | 12572 | 79 |
| | Without fertilizers | 22450 | 7666 | 14774 | 1707 | 8069 | 193 |
| 7. | $P_{60}K_{60}$ | 22750 | 12240 | 10510 | 2690 | 12619 | 86 |
| | $P_{90}K_{90}$ | 23300 | 14627 | 8673 | 3139 | 16270 | 59 |
| | Without fertilizers | 32350 | 10485 | 21865 | 1621 | 7825 | 209 |
| 8. | $P_{60}K_{60}$ | 33650 | 15559 | 18091 | 2312 | 11275 | 116 |
| | $P_{90}K_{90}$ | 33950 | 17946 | 16054 | 2643 | 12819 | 89 |
| | Without fertilizers | 30600 | 10180 | 20420 | 1663 | 7597 | 201 |
| 9. | $P_{60}K_{60}$ | 31400 | 15054 | 16446 | 2397 | 11069 | 109 |
| | $P_{90}K_{90}$ | 31700 | 22515 | 9585 | 3551 | 16315 | 43 |
| | Without fertilizers | 12650 | 5099 | 7551 | 2015 | 13418 | 148 |
| 10. | $P_{60}K_{60}$ | 13150 | 9872 | 3278 | 3754 | 25313 | 33 |
| | $N_{60}P_{60}K_{60}$ | 19650 | 12045 | 7605 | 3065 | 16060 | 63 |

The lowest indicators of economic efficiency were registered on cereal grass stands, following the introduction of $P_{60}K_{60}$, with a net profit of 3278 UAH/ha and profitability of 33%, which is by 2.3-4.5 times less. In addition, the cost of 1 ton of feed units and crude protein totalled 3754 and 25313 UAH respectively, which is by 1.8-1.9 times as much like in the fertilizer-free version.

Nitrogen supplement at a dose of $N_{60}$ on cereal grass stands increased the net profit to 7605 UAH/ha, which was higher than in the option without fertilizers.

Analysis of energy efficiency of cultivation of perennial legume-cereal grass stands on different fertilizer backgrounds showed that the total energy consumption per 1 ha, as well as energy consumption per 1 ton of fodder units in legume-cereal and cereal grass stands, varied between 13.0-27.0 and 3.14-7.15 GJ respectively (Table 3).

The total energy consumption per 1 ha and energy costs per 1 ton of feed units for growing legume-cereal grass stands with the inclusion of different legumes, regardless of the cereal component, on the background of P90K90 fluctuated within the range of 3.98-6.15 GJ, which is by 1.1 times higher than the $P_{60}K_{60}$ background (3.66-7.15 GJ) and by 1.3-1.4 times more as opposed to the fertilizer free variant (3.14-5.68 GJ). On the contrary, the recoupment of the total energy consumption with the output from 1 ha of exchange (BEK) and gross energy (KEE) for growing legume-cereal grass stands following the introduction of P90K90 was the lowest with indicators 2.1-2.9 GJ/ha and 4.4-6.7 GJ/ha respectively, which is by0.1-0.3 GJ/ha and 0.2-0.7GJ/ha less compared to the $P_{60}K_{60}$ background, and by 0.7-0.8 GJ/ha and 1.6-1.9 GJ/ha lower in comparison to fertilizer-free variant.

The inclusion of perennial legumes into cereals on non-nitrogenous fertilizer backgrounds (options without fertilizers and with the introduction of $P_{60}K_{60}$) significantly improved the energy efficiency of growing legume-cereal grass stands. In these variants, the indicators BEK and KEE increased by 0.6-1.5GJ and 2.3-3.9 GJ respectively, and energy costs per 1 ton of feed units decreased by 1.50-2.16 GJ.

Legume-cereal grass stands and cereal grass stands, containing a meadow brome - reed fescue - intermediate wheat grass mixture, required slightly less (by 0.20-0.35 GJ) energy costs per 1 ton of feed units in contrast to the inclusions of red fescue grass - awnless brome - italian ryegrass mixture.

**Table 3.** Economic efficiency of growing perennial legume-cereal grass stands on different fertilizer backgrounds (average over 2015-2018).

| Experiment option | Fertilizers | Energy costs, GJ/ha | KEE GJ/ha | BEK GJ/ha | Energy costs per 1 ton of feed units, GJ |
|---|---|---|---|---|---|
| 1. | Without fertilizers | 18.3 | 7.8 | 3.4 | 3.53 |
| | $P_{60}K_{60}$ | 22.8 | 6.4 | 2.8 | 4.25 |
| | $P_{90}K_{90}$ | 25.1 | 6.0 | 2.6 | 4.67 |
| 2. | Without fertilizers | 15.7 | 6.7 | 2.9 | 4.13 |
| | $P_{60}K_{60}$ | 21.1 | 5.1 | 2.2 | 5.44 |
| | $P_{90}K_{90}$ | 23.0 | 4.8 | 2.1 | 5.74 |
| 3. | Without fertilizers | 19.0 | 8.1 | 3.5 | 3.39 |
| | $P_{60}K_{60}$ | 23.4 | 6.7 | 2.9 | 4.08 |
| | $P_{90}K_{90}$ | 25.6 | 6.2 | 2.7 | 4.42 |
| 4. | Without fertilizers | 18.3 | 7.8 | 3.4 | 3.47 |
| | P60K60 | 22.5 | 6.4 | 2.8 | 4.21 |
| | $P_{90}K_{90}$ | 24.7 | 6.0 | 2.6 | 4.48 |
| 5. | Without fertilizers | 13.0 | 4.4 | 2.1 | 5.68 |
| | $P_{60}K_{60}$ | 17.3 | 3.4 | 1.6 | 7.15 |
| | $N_{60}P_{60}K_{60}$ | 22.8 | 4.0 | 1.9 | 6.15 |
| 6. | Without fertilizers | 18.4 | 7.8 | 3.4 | 3.48 |
| | $P_{60}K_{60}$ | 22.7 | 6.4 | 2.8 | 4.24 |
| | $P_{90}K_{90}$ | 25.1 | 6.0 | 2.6 | 4.54 |
| 7. | Without fertilizers | 16.9 | 7.1 | 3.1 | 3.76 |
| | $P_{60}K_{60}$ | 21.2 | 5.3 | 2.5 | 4.66 |
| | $P_{90}K_{90}$ | 23.3 | 5.5 | 2.4 | 5.00 |
| 8. | Without fertilizers | 20.3 | 8.5 | 3.7 | 3.14 |
| | $P_{60}K_{60}$ | 24.6 | 7.4 | 3.2 | 3.66 |
| | $P_{90}K_{90}$ | 27.0 | 6.7 | 2.9 | 3.98 |
| 9. | Without fertilizers | 19.6 | 8.3 | 3.6 | 3.20 |
| | $P_{60}K_{60}$ | 24.1 | 6.9 | 3.0 | 3.84 |
| | $P_{90}K_{90}$ | 26.3 | 6.4 | 2.8 | 4.15 |
| 10. | Without fertilizers | 13.4 | 4.6 | 2.2 | 5.30 |
| | P60K60 | 17.7 | 3.6 | 1.7 | 6.73 |
| | $N_{60}P_{60}K_{60}$ | 24.1 | 4.0 | 1.9 | 6.13 |

Both grass stands showed the highest total energy expenditure per hectare subject to the application of mineral fertilizers at the rate of $N_{60}P_{60}K_{60}$ with indicators 22.8-24.1 GJ, which is by 1.1-1.4 times higher compared to the $P_{60}K_{60}$ background and by 1.8 times up from the option without fertilizers. Mean while, energy costs per 1 ton of feed units turned out to be the highest following the introduction of $P_{60}K_{60}$. The return on the total energy expenditures with the output from 1 ha of exchange and gross energy following the introduction of $P_{60}K_{60}$ was the smallest with indicators of 1.6-1.7 GJ and 3.4-3.6 GJ respectively, which is by 0.2-0.3 GJ and 0.4-0.6 GJ respectively less compared to the background $N_{60}P_{60}K_{60}$, besides, it is by 0.5 and 1.0 GJ lower in contrast to the option without fertilizers.

## Conclusion

The findings of this study show that cultivation of perennial legume-cereal grass stands without mineral fertilizers in the Carpathian region possesses the following features: the net profit totals 11.1-21.9 thousand UAH/ha, the level of profitability is 151-210%, the prime cost of 1 ton of feed units makes 1.6-2.0 thousand UAH, BEK is 2.8-3.7 GJ/ha, KEE is 6.4-8.5 GJ/ha, energy costs per 1 ton of feed units account for 3.1-4.3 GJ. Cultivation of bird's foot trefoil in the companion sowings with cereals provides the highest indicators of economic and energy efficiency. Among the fertilizer options, the best cost-effectiveness options were with the application of phosphorus-potassium fertilizers at the rate of P60K60.

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