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Production and economic potential of hay and seed production from alfalfa (*Medicago sativa* L.) in a two-crop cultivation technology

Produkčný a ekonomický potenciál výroby sena a semena lucerny siatej (*Medicago sativa* L.) v dvojúrodovej technológii pestovania

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ABSTRACT

The article evaluates the trends of costs and revenues (returns) from the production of hay and alfalfa seed in two variants of phosphorus and potassium fertilization in three years of use. The base for the cost evaluation was the three-year research results of the cultivation of alfalfa sown in the field operational trials of the seed company. The costs and revenues of the production of hay from the first mowing and seed from the second mowing were evaluated for three useful years. Economic analysis was based on the technological and economic parameters used by the Research Institute of Agricultural Technology in Prague. The obtained alfalfa seed yields were statistically evaluated by multifactor analysis of variance (ANOVA) with verification of the plausibility of differences by Tukey's HSD test at the 99% probability level (a=0.01). The Research Institute of Agricultural and Food Economics in Bratislava calculation formula was used to monitor the costs and returns of sown alfalfa. In the productive years as well as the three-year average of hay and seed yields, the cultivation of sown alfalfa was highly profitable. The profit in variant V1 in the years was presented in the amount of 1 488.11 Eur/ha to 1 732.20 Eur/ha, variant V2 1 449.05 Eur/ha to 1 653.55 Eur/ha and in the average of three useful years 1 542.93 Eur/ha. The Return on Costs (ROC) was presented with values of high efficiency of hay and alfalfa seed production, both without the support and with EU support. These supports are the single area payment scheme (SAPS), the redistributive payment and payment for agricultural practices beneficial for the climate and the environment.

Keywords: alfalfa, hay and seed harvest, cultivation technology, costs, revenues, profit

ABSTRAKT

Príspevok hodnotí trendy nákladov a výnosov z výroby sena a semena lucerny siatej v dvoch variantoch hnojenia fosforom a draslíkom v troch úžitkových rokoch. Východiskom pre hodnotenie nákladovosti boli trojročné výsledky výskumu pestovania lucerny siatej v poľných prevádzkových pokusoch semenárskeho podniku. Náklady a výnosy výroby sena z prvej kosby a semena z druhej kosby boli hodnotené za tri úžitkové roky, Vychádzalo sa pri tom z technologických a ekonomických parametrov používaných Výskumným ústavom poľnohospodárskej techniky v Prahe. Získané úrody semena lucerny siatej boli štatisticky vyhodnotené viacfaktorovou analýzou rozptylu (ANOVA) s overením hodnovernosti rozdielov Tukeovým HSD testom pri 99% hladine pravdepodobnosti (a=0,01). Na sledovanie nákladov a výnosov lucerny siatej bol použitý kalkulačný vzorec Výskumného ústavu ekonomiky poľnohospodárstva a potravinárstva Bratislava. V úžitkových rokoch ako aj trojročnom priemere úrod sena a semena bolo pestovanie lucerny siatej vysoko ziskové. Zisk vo variante V1 v rokoch bol prezentovaný sumou 1 488.11 Eur/ha až 1 732.20 Eur/ha, variant V2 1 449.05 Eur/ha až 1 653.55 Eur/ha a v priemere troch úžitkových rokov 1 542.93 Eur/ha. Rentabilita nákladov (ROC) sa prezentovala hodnotami vysokej efektívnosti výroby sena a semena lucerny siatej a to bez podpory aj s podporou EÚ.

Kľúčové slová: lucerna siata, úroda sena a semien, technológia pestovania, náklady, výnosy, zisk

INTRODUCTION

In the lowland regions of Slovakia, alfalfa cultivation holds a significant place in the structure of fodder crops, even in the context of the climate crisis (Lapin, 2014; Rotz, 2022). Historical records show that average annual temperatures are consistently rising in most countries around the world, along with changes in precipitation patterns (Lindenmayer et al., 2010; Rotz, 2022). These changes affect the production of alfalfa and other fodder crops in many regions. Scientific evidence strongly supports that the cause of warming is the increasing concentration of carbon dioxide (CO_2) in the atmosphere, primarily due to the burning of fossil fuels. This is confirmed by a high correlation between global temperature and the concentration of CO_2 in the atmosphere. Measurements have documented approximately a 30% increase in CO_2 concentration since 1960. However, increased levels of carbon dioxide in the atmosphere can, under certain conditions, stimulate the growth of many crops, including alfalfa (Rotz, 2016; Trebicky and Finlay, 2019; Rotz, 2022). The greatest threat to the long - term sustainability of fodder and alfalfa production is the availability of water, especially in dry areas where production depends on irrigation (Lindenmayer et al., 2010; Rotz, 2022). It is assumed that the climate will become warmer and drier. Therefore, it seems highly likely that the summer production of fodder, including alfalfa, will decrease (Ruget et al., 2008).

Alfalfa is Slovakia's most productive perennial and multi-harvest protein fodder crop grown on arable land (Kováč and Jakubová, 2018; Holúbek, 2018; Kováčik and Ryant, 2019). It originates from the continental conditions of the high plateaus of Central Asia, which have fixed traits of drought resistance and resilience to low temperatures in its genome, as well as the corresponding morphological structure of plants (Grznár, 2004; Ďurková, 2007; Vozár, 2007). The best prospects for its successful cultivation are in the lowland, hilly, and low basin regions. Mazur and Lukniš (1986) recommend cultivating alfalfa on 18.6% of very suitable and 19.4% of suitable total agricultural land. Jančovič and Holúbek (1999) recommend growing alfalfa in these areas for 3-4 years, mainly to produce hay, wilted silage, green fodder, and dry commodities. During the utilisation years, hay yields should reach 9 t/ha (Jamriška, 1997).

According to Ševečla (1965), seed yields in the second harvest should reach values of 320 to 400 kg/ha. Due to the reduction in cattle numbers in the Slovak Republic (SR) from 1.7 million (1990) to 442000 and pigs from over 2.5 million to 400000 in 2020, we also recorded a decrease in cultivation areas of both perennial and annual fodder crops. The sowing areas of perennial fodder crops decreased by 70 659 hectares, comparing 204 798 hectares in 1990 and 134 139 hectares in 2020. The decline is particularly noticeable in alfalfa, from 118 125 hectares to 53 793 hectares, i.e., by 64 332 hectares. The yields of alfalfa hay in the SR reached 6.51 t/ha in 2019 and 6.25 t/ha in 2020 (Statistická ročenka České a Slovenské Federativní republiky, 1990; Štatistická ročenka Slovenskej republiky, 2020) and seeds from 483 kg/ha to 785 kg/ha (Ševečla, 1965). The decisive factor in the economic stability of alfalfa cultivation is the efficiency of its production, presented by costs and returns. Costs are an important synthetic indicator of the economic activity of agricultural enterprises. They reflect all aspects of the production process, from the level of technical equipment of enterprises, labour productivity, intensity, and organization of production, the influence of nature and economic conditions, and of course, the price of energy inputs, which in recent years have significantly affected the overall economy (Haupvogel, 1992; Grznár, 2004; Bielik et al., 2011; Holúbek, 2018). In the cost structure of alfalfa fodder production, costs for industrial fertilizers and machinery operations dominate. As a nitrogen donor (nodule-forming bacteria), alfalfa responds less to nitrogen from industrial fertilizers. However, it requires phosphorus-potassium fertilization and sulphur fertilization (Fecenko and Ložek, 2000). According to Kováč and Jakubová (2018), the highest costs for growing perennial fodder crops are in the sowing years. In conventional alfalfa cultivation technology, variable costs are represented by the sum of 619.82 Eur/ha, fixed costs by the sum of 165.86 Eur/ha, and total costs together at 785.68 Eur/ha.

With Slovakia's entry into the common economic area of the EU in 2004, Slovakia committed to adopting regulations, common rules, and conditions of the Common Agricultural Policy (CAP). A significant part of the CAP is the agricultural support policy, and within it, subsidies aimed at helping achieve prosperity for agricultural enterprises (Ďuričová, 2014). The original purpose and aim of agricultural support (Foltýn et al., 2008) were to improve the pension situation of agricultural producers, considering broader societal interests. As a provider of support, the state decides on the selection of commodities and the level of support for selected commodities within its agricultural policy (Bečvářová, 2008). The idea of promoting plant production with subsidies should be extended to support aimed at better market applicability of plant products, including alfalfa. In this case, it is also about supporting better market applications for animal products. The effort to reduce costs for the disposal of unmarketable products has been mistakenly interpreted as a need to reduce production. The global market could absorb even greater production at better prices, and quality, and under better marketing conditions (Baco, 2009).

MATERIAL AND METHODS

In the context of the research task of the Institute of Agronomical Sciences, SUA in Nitra, the effects of mineral nutrition and its use were examined in connection with the cost of producing hay and alfalfa seeds in operational conditions. The experimental trial was established according to the Central Control and Testing Institute in Agriculture methodology over three years. Experimental work was carried out in the cadastral area of Topoľčany on the former state-owned seed farm Nový Svet. The area of interest consists of chernozems on loess. The soils are deep with a medium to deep topsoil, the humus horizon is up to 25 centimetres. The topsoil is slightly humus clay (1.6%). The soil reaction is slightly acidic to neutral (6.5 – 7.2 pH).

The test site is in a moderately dry and warm climatic area. The long-term average annual precipitation is 610 mm with an average annual temperature of 9.3 degrees Celsius. In the first experimental year, the precipitation reached 542.10 millimetres during the vegetation period, in the second year 330.90 millimetres, and in the third year 231.40 millimetres, with temperatures of 15.5 °C in the second year, 16.3 °C, and in the third year 15.4 °C. Alfalfa crops were established using the summer-autumn cultivation technology in two variants of fertilization with industrial fertilizers: variant V1 35 kg phosphorus per ha in the form of superphosphate and 100 kg potassium per ha of potassium salt (60%), variant V2 52.5 kg phosphorus per ha and 150 kg potassium per ha. After the harvest of the previous crop, soil preparation was carried out. Lucerne alfalfa crops were established for regular operational purposes by sowing in August without a cover crop. The Palava variety was sown into the prepared soil at a rate of 15 kg/ha, using a Saxonia seeder. The yields of hay and alfalfa seeds were evaluated over three years of use. In each year of use, alfalfa was used for hay production in the first cut and for seed production in the second cut. The costs of producing hay and alfalfa seeds in two utilization systems consisted of work associated with soil preparation, fertilization, sowing, care, and harvesting.

The study was based on the technological and economic parameters used by the Research Institute of Agricultural Engineering in Prague Ruzyně (Melillo et al., 2014). Direct costs to produce hay and seeds were recalculated from May 25, 2023 (1 Eur = 23.64 CZK). The prices of industrial fertilizers for 1 kg of P_2O_5 in superphosphate and K_2O 60% potassium salt were provided by the Research Institute of Chemical Technology Bratislava and the Agrochemical Company Levice. A calculation formula from the Ecological & Forest Research Agency's final report was used to track the costs and returns of producing hay and sown alfalfa seeds.

RESULTS AND DISCUSSION

Evaluation of costs and revenues to produce sown alfalfa hay in the 1st harvest

The basis of agricultural production in the lowland regions of Slovakia is plant production. Until the 90s, the structure of plant production was relatively stable.

Tightly sewn cereals were cultivated in an area of 40-50%, and fodder and fodder tubers occupied 20-30% of the areas. The remaining areas were sown with technical crops, mainly oilseeds, sugar beets, potatoes, and vegetables. After Slovakia entered the EU, the structure of plant production gradually changed in the context of implementing some principles of the common agricultural policy (Mindaš et al., 2011). The share of technical crops, especially oilseeds, is increasing, and the area of potatoes, vegetables, legumes, and especially annual and perennial forage is decreasing. This presented PP - imbalance on commodity agricultural markets causes significant annual changes in sown areas in production and economic indicators of soil fertility, protection, and creation of forest-agricultural landscape. The photosynthetic potential of sown Lucerne alfalfa is limited by water, nutrients, sunlight, temperature, and other factors. The limiting factor of yields are precipitations, and their time distribution during the vegetation period, nutrition, and fertilization. Currently, the fertilization of field crops is considered the basis of modern agricultural production. This is because it is considered the main source of nutrients that participate in plant metabolism, which is closely related to the yield and quality of cultivated crops (Kováčik and Ryant, 2019). We present the results of the reaction of sown alfalfa to phosphorus and potassium fertilization on hay yields in Table 1.

The yield of hay in the evaluated years in variant V1/Y1 reached 4.98 t/ha and in V1/Y3 5.53 t/ha, variant V2/Y1 5.03 t/ha and V2/Y3 5.47 t/ha, which on average over the evaluated years represented 5.17 t/ha in variant V1 and 5.19 t/ha in variant V2. In this context, it is important to note that the costs of establishing sown alfalfa crops (ploughing, soil preparation for sowing, industrial fertilizers and their application, and seeds) were divided into three useful years in equal shares. In the mentioned context, the cost per hectare for hay production in the first harvest reached 362.60 Eur/ha in variant V1 and 249.11 Eur/ha in variant V2, and the revenues from produced hay were 298.00 Eur/ha in variant V1 up to 331.80 Eur/ha in variant V2 (Table 1). Profitability from production showed a loss in both fertilization variants.

Evaluation of costs and revenues from the production of sown Lucerne alfalfa seeds in the 2nd harvest

The complexity of trials with nutrition and fertilization of sown alfalfa for seed is fully reflected in this topic, which often leads to different, in many cases, even negative results (Krajčovič et al., 1968). The results of sown alfalfa seed yields in the evaluated years and fertilization variants are shown in Table 2. In our trials, the highest yield of sown alfalfa seeds was achieved in the third year of use at 556.88 kg/ha in the fertilization variant V1. The lowest yield in the second year of use was 49.59 kg/ha in the fertilization variant V2. Overall, in the second evaluated year, significantly lower yields were achieved than in the first and third evaluated years (Table 2). The average yields of seeds and the natural state of sown Lucerne alfalfa in three evaluated years were evaluated by the method of variance analysis. The statistical evaluation is shown in Tables 3 and 4 and Figure 1. Costs and revenues from the production of sown alfalfa seeds in the years of use in ecological cultivation technology are shown in Table 1. The costs in variant V1 per hectare of sown alfalfa cultivation were 145.38 Eur/ha to 148.31 Eur/ha, and in variant V2 146.84 Eur/ha to 148.10 Eur/ha. The cost structure is dominated by the cost of combined harvesting (60 Eur/ha). In the given soil-ecological and climatic conditions, the production of sown alfalfa seed is highly profitable. The profit in variant V1 was represented by a sum of 1 547.57 Eur/ha to 1 766.46 Eur/ha and in variant V2 by a sum of 1 575.10 Eur/ha to 1 754.46 Eur/ha. The influence of higher intensity of PK Fertilization variant V2 in revenues and profit did not demonstrably manifest itself.

Multifactor variance analysis confirmed the statistically highly significant influence of the year on the production of alfalfa seeds evaluated in three utilization years and two fertilization variants (Table 3).

Testing the differences between average yields of alfalfa seeds using the Tukey test confirmed statistically highly significant differences between the evaluated trial years (Table 4).

Table 1. Costs and revenues of the production of alfalfa hay and seed in usage years and fertilization variants

Indicators	Units	Costs for work operations and main parameters Usage years					
		Y1		Y2		Y3	
Fertilization Variants (V)		V I	V 2	V I	V 2	V I	V 2
Tillage	Eur/ha	20.00	20.00	20.00	20.00	20.00	2000
Soil preparation	Eur/ha	6.00	6.00	6.00	6.00	6.00	6.00
Industrial fertilizers application	Eur/ha	102.60	168.95	102.60	168.95	102.60	168.95
Sowing	Eur/ha	5.15	5.15	5.15	5.15	5.15	5.15
Seeds	Eur/ha	30.00	30.00	30.00	30.00	30.00	30.00
Mowing 1st cut	Eur/ha	15.52	15.52	15.52	15.52	15.52	15.52
Raking hay	Eur/ha	11.54	11.54	11.54	11.54	11.54	11.54
Pressing hay	Eur/ha	41.16	41.16	41.16	41.16	41.16	41.16
Loading and transporting hay	Eur/ha	12.02	12.02	12.02	12.02	12.02	12.02
Production and administrative	Eur/ha	118.77	118.77	118.77	118.77	118.77	118.77
Total costs	Eur/ha	362.66	429.11	362.66	429.11	362.66	429.11
Hay yield	t/ha	4.98	5.03	5.02	5.08	5.53	5.47
Cost per ton of hay	Eur/ha	72.82	85.31	72.24	84.47	65.58	78.44
Revenue from hay	Eur/ha	298.00	301.80	301.20	303.00	331.80	328.20
Profit from hay	Eur/ha	-64.66	-127.31	-61.45	-126.11	-30.86	-100.91
Desiccation of alfalfa	Eur/ha	40.00	40.00	40.00	40.00	40.00	40.00
Combine threshing	Eur/ha	60.00	60.00	60.00	60.00	60.00	60.00
Straw transportation	Eur/ha	23.95	23.95	23.95	23.95	23.95	23.95
Post-harvest treatment	Eur/ha	22.47	22.89	21.43	21.84	24.36	24.15
Seed yields	Eur/ha	321.92	327.34	307.81	312.90	348.14	345.92
Cost per hectare	Eur/ha	146.42	146.84	145.38	145.79	148.31	148.10
Revenue from seeds	Eur/ha	1770.56	1800.37	1692.95	1725.95	1714.77	1902.56
Profit from seeds	Eur/ha	1624.08	1653.53	1547.57	1575.10	1760.46	1750.46

Source: Own processing

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Table 2. Average yields of seeds in the natural state of sown alfalfa in three evaluated years (kg/ha)

Test years (Y)	Variants of yields in years of use and variants of fertilization					
Fertilization Variants (V)	V1	V2	V1	V2	V1	V2
Y1	511.58	516.34	448.15	468.85	371.83	379.36
Y2	50.19	49.59	52.86	52.71	115.73	116.61
Y3	404.00	415.75	422.42	417.14	556.88	541.80
Average	321.92	327.23	307.81	312.90	348.15	345.92

Source: own processing

Table 3. One-way tests of the significance

Effect	Seed yield (Field trial alfalfa)				
	SS	d	MS	F	p
Fertilization	33	1	33	0,0094	0,924094
Trial year	582671	2	291336	82,1500	0,000000
Error	49649	14	3546		

Source: own processing

Table 4. Homogeneous groups (1 – 2) – seed yield, Tukey HSD test, α – 0.01

Trial Year	Seed Yield	1	2
2nd Trial Year	72,.5		****
1st Trial Year	449.35	****	
3rd Trial Year	459.67	****	

Source: own processing

The analysis of variance using the scraping method provided yield effects (deviations) compared to the average of the trial for interactions between Fertilizer Variants x trial years (Chloupek and Ehrenbergerová, 1995). The highest positive difference compared to the three-year yield average was determined in the first year of evaluation and the third year of use (sainfoin crops, which was +186.94 kg/ha). The highest negative difference was recorded in the third year of evaluation and in the third year of use (which was -139.92 kg/ha).

In general, we can state that sainfoin seed production is significantly influenced by the conditions of the seed year, but also the production year.

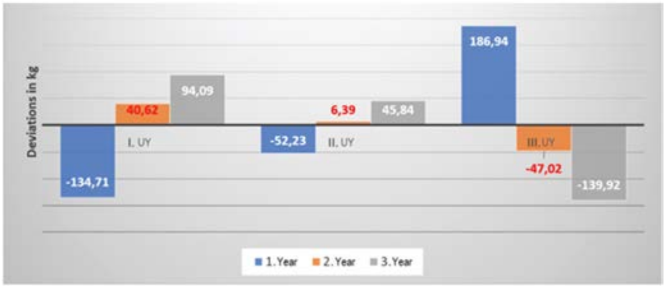

Figure 1. Group bar chart of sainfoin seed yield deviations in fertilizer variants V1+V2 and evaluated trial and utility years

Source: own processing

Synthesis of costs and revenues of sainfoin grown for hay and seed in the evaluated years

For a comprehensive evaluation of the results of growing sainfoin in the first cut for hay production as feed for farm animals and seed for reproduction in the second cut as a synthetic indicator, we present in Table 5. Revenues and profit from growing sainfoin significantly influenced the costs of establishing stands, which were redistributed to utility years in the same amount. The technological measures significantly influenced the profitability of costs (ROC) as an additional revenue indicator (Table 5), which is increased by the EU support policy. The highest yield of sainfoin seeds was achieved in the third year of use, 556.88 kg/ha in the V1 fertilization variant. The lowest yield was determined in the second year of use 49.59 kg/ha in the V2 fertilization variant. Overall, significantly lower yields were achieved in the second evaluated year than in the first and third evaluated years (Table 1).

Table 5. Synthesis of costs and revenues of hay and sainfoin seed production in the evaluated years and fertilizer variants

Indicator		Years of use					
Fertilizer Variants	units	V1	V2	V1	V2	V1	V2
Costs	Eur/ha	509.08	575.95	506.04	574.90	511.37	577.21
Revenues	Eur/ha	2068.55	2102.17	1994.15	2023.95	2243.95	2223.76
Profit	Eur/ha	1560.08	1526.22	1488.11	1449.05	1732.20	1653.55
Revenues + 200 Eur support	Eur/ha	2268.55	2301.17	2194.15	2223.95	2443,57	2423.76
The ratio of costs to revenues without EU support	%	0.246	0.274	0.254	0.284	0.228	0.256
The ratio of costs to revenues with EU support	%	0.312	0.337	0.322	0.348	0.291	0.318

Source: own processing

CONCLUSION

The following conclusions result from the results of the research in the double-crop technology (hay/seed) of sainfoin cultivation. Hay yields from the first mowing, expressed in the average of three years, reached 5.17 t/ha in variant V1 and 5.19 t/ha in variant V2, seed yields 325.94 kg/ha in variant V1 and 328.72 kg/ha in variant V2. Multifactor variance analysis confirmed a statistically highly significant influence of the year on the seed production of sainfoin. The analysis of the costs of sainfoin cultivation in the first mowing for hay production and in the second mowing for seed confirmed the justification of the double-crop system of sainfoin cultivation in production soil-climatic conditions. This is documented by the achieved results of hectare yields, costs, and revenues and the profitability of revenues without support and with support. The cost-effectiveness (ROC) of total costs to revenues as a supplementary indicator to revenue profitability was presented with higher efficiency values in variant V2, which can be increased by the EU's support subsidy policy.

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