C R O P   M A N A G E M E N T

IMPACT OF FERTILIZER RATES ON THE YIELD AND QUALITY OF ALFALFA ON A SOD PODZOLIC LOAMI SAND

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Abstract
A 5-year field study was conducted near Skriveri, Latvia at the Research Institute of Agriculture of the Latvian University of Agriculture. The results of investigations with alfalfa on well-cultivated sod-podzolic light loamy soil are presented. It is shown that the optimum NPK fertilizer dose in consideration of the size of the yield of dry matter and its nutritive value was $P_{120}K_{160}$, comes to 8.10 t ha^{-1}. Mineral fertilizers favour the rise of the collection of total protein, with higher doses the collection of protein increased by 1.5 times. It is found that in the optimum trial variant ($N_{20}P_{120}K_{160}$) provided the most alfalfa yield with good quality, the specific nitrogen removal amounted to 266 kg ha^{-1}; P_2O_5 -55 kg ha^{-1} and K_2O -271 kg ha^{-1}.

Key words: alfalfa, NPK fertilizer, dry matter, protein

Introduction
The yearly deficiency of protein in Latvian feeds is about 20-30%; this is especially apparent during the stalled periods. The existing disproportion between general food value of feeds and their protein leads to significant over expenditure of the feeds and to the rise of the costs of animal produce.

Vegetable fodder protein production growth is possible at the expense of expansion of the sown area and raising the level of the crop yield of alfalfa.

The value of alfalfa as a fodder crop is determined by its macrobiosis and high protein content. Alfalfa produces high yields in both clean crops and together with grass. One of the key conditions for the high yields of alfalfa is the optimal introduction of mineral fertilizers. (Marvin, Robert, 2002). This crop, which is cultivated for feed, has a well-known positive reaction to the introduction of phosphoric/potassium fertilizers on sod-carbonated soils (Hall, Smiles, Dickerson, 2000). But data on the mineral nutrition of alfalfa, which is cultivated for feed, when combining different NPK fertilizers on sod-podzol soils, so far are not sufficient (Kindler, 1996).

Materials and Methods
Field tests were carried out by 24 variants' scheme, which corresponds to 1/9 (6x6x6) of the full factorial experiment (Peregudov, 1981). The results of the research are processed for 5 testing years.

We examined the efficiency of six levels of fertilizers (including zero level), three factors N, P, K, where the unit is equal to: N- 20; P_2O_5- 60; K_2O- 80 kg ha^{-1}.

We studied the cultivation of alfalfa for feed with double harvesting. Values of yields are given in tons of completely dry matter from 1 ha.

Phosphoric fertilizers were introduced manually in the early spring in one step as granulated superphosphate, nitrogen (ammonia nitrate) and potash (potassium chloride) fertilizers – separately, in equal parts, - in spring and after the first hay crop.

The sod-podzol sandy-loam lay with morainic friable loamy sand. The effervescence from HCl from the depth of 80-90 cm, the thickness of topsoil – 28-30 cm, pH_{KCl} – 6.1-6.4. Contents of available phosphorus P_2O_5 – 60-85 mg kg^{-1} and available potassium K_2O – 101-124 mg kg^{-1} of soil (Egner-Riehm DL method.) Contents of organic matter – 15 – 19 g kg^{-1} (Tyurin method).

Soil was limed on the basis of full norm by hydrolytic acidity (5 ton ha^{-1} of $CaCO_3$ in form of slate ash), consequently pH $_{KCl}$ of the topsoil increased to 6.6-6.8. During the experiments, introducing mineral fertilizers, repeated acidulation did not occur. The seeding rate of alfalfa – 20 kg ha^{-1}, space between rows – 15 cm. In the second year of alfalfa's life – early spring harrowing and in the third year of life - disking.
Data on crops were processed by regression method with application of the model:

$Y=a_0+a_1N+a_2P+a_3K+a_4N^{0.5}+a_5P^{0.5}+a_6K^{0.5}+a_7(NP)^{0.5}+a_8(NK)^{0.5}+a_9(PK)^{0.5}$,
where: Y is yield, a_0 is absolute term, which defines yield without fertilizers (variant $N_0P_0K_0$), a_1 to a_9 are coefficients, which define the impact of the NPK fertilizers on yield (MATLab, 2005).

The evaluation of the reliability of values under study was conducted on the level of significance of 0.95. The determination of the quality of grass dry matter, of all agrochemical characteristics of soil and plants, and the examination of grass stand's formation were conducted according to standard methods.
The meteorological conditions of the vegetative season in the particular years of the studies differed from the long-term average, but did not significantly influence the crop yield of alfalfa.

Results and Discussion

After the Results of the Plant Breeding Department data, the crop yield of alfalfa's dry matter on neutral soils was 2.8 to 13.5 tons per ha, and changed by year and variety. As is seen from the table 1, yields are not stable (Results…, 2007). By using mineral fertilizers it is possible to get more stable yields, and by using mathematical models it is possible to plan the introduction of fertilizers.. Therefore, it is very important to know not only the impact of separately introduced fertilizers, but also their interaction. Considering that the soil was weak-acidic, alfalfa developed well in our experiment.

Table 1.Crop yield of alfalfa's dry matter in 2000-2004, tons per ha, (results of Plant Breeding Department)

	Dry matter yield, t ha^{-1}				
Variety	2000 g.	2001 g.	2002 g.	2003 g.	2004 g.
Skriveru	3.2	14.3	10.9	8.9	5.7
Magda	3.0	13.3	10.5	8.5	6.5
ABT-205	2.8	12.6	10.4	8.3	5.5
Jitka	2.7	11.9	9.7	7.8	5.8
Nr.60	3.3	13.5	11.1	9.1	6.7
Vernal	3.4	13.4	10.6	8.8	6.4
Ņiva	2.9	12.3	10.7	8.6	6.6
Multigen	2.2	10.5	8.3	7.9	5.0
Birute	3.5	12.7	10.8	9.5	6.2
Karli	3.6	12.2	10.2	10.7	7.5
Average	3.1	12.7	10.3	8.1	6.2
Least significant difference at $\rho \leq 0.05 = 0.16$ t ha^{-1}					

In each year of the study, the crop yield of completely dry matter (DM) of alfalfa ($Y_{1,2,3}$ accordingly by the years of usage, and Y_4 – for five testing years) in fertilized variants was, on average, 2.1- 2.4 times higher than in the control variant. This dependence was defined by the following production functions:
$Y_1=6.22-0.44N^{0.5}+0.45(NP)^{0.5}+0.65(NK)^{0.5}$; $R^2=0.90$
$Y_2=7.11+0.19N+0.54(PK)^{0.5}$; $R^2=0.81$
$Y_3=6.93-0.20N+0.56N^{0.5}+0.52K^{0.5}+0.16(NP)^{0.5}$; $R^2=0.96$
$Y_4=6.93+0.56K^{0.5}+0.20(NP)^{0.5}+0.22(PK)^{0.5}$; $R^2=0.91$

Judging by the value of absolute term of equations, the fluctuations of the crop yield of DM, depending on the year of usage, excluding the impact of fertilizers, were insignificant. Generally, yield depended on the level of applied doses of fertilizers, which is indicated by the high value of the determination coefficient (R^2).

The increasing dozes of nitrogen provided for the continuous growth of alfalfa yields i the second year (Y_2) of grass stand usage.

The increasing doses of nitrogen provided for the consecutive continuous growth of the alfalfa yield in the second year of usage of the grass stand. The alfalfa of the first year (Y_1) of usage was negatively influenced by separately introduced nitrogen fertilizers, and the alfalfa of the third year (Y_3) of usage, after reaching maximal yield with N_{40}, was influenced negatively.

Persistent influence on the yield of DM was shown by phosphoric and potash fertilizers (Table 2). Increases of yields after their combined introduction grew with the increase of doses. Both types of fertilizers were identical. However, the phosphoric fertilizer was effective only when combined with nitrogen and potash fertilizers. Potash fertilizer was effective both separately and combined with NP fertilizers.

Table 2. The crop yield of the absolutely dry matter (Y_4) of alfalfa, depending on fertilizers, in average for 5 testing years.

N kg ha^{-1}	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}			
		0	80	160	240
0	0	6.57	7.14	7.37	7.55
	60		7.36	7.69	8.93
	120		7.45	7.82	8.1
	180		7.52	7.91	8.22
20	0				
	60	6.77	8.56	7.88	7.55
	120	6.85	7.73	8.11	8.14
	180	6.92	7.87	8.26	8.38
40	0				
	60	6.86	7.64	7.97	8.22
	120	6.97	7.85	8.22	8.5
	180	7.07	8.01	8.41	8.71
60	0				
	60	6.92	7.7	8.03	8.28
	120	6.06	7.94	8.31	8.59
	180	7.17	8.13	8.52	8.52

From the paired combinations, the PK fertilizers had the strongest impact slightly weaker – NP fertilizers.

The maximum practically justified growth of the yield of DM was about 1.54 t ha^{-1}, and was reached by combining 20 kg ha^{-1} of N, 120 kg ha^{-1} of P_2O_5 and 160 kg ha^{-1} of K_2O.

The recoupment by increase of the yield of DM by introducing potassium and phosphoric fertilizers, as their dozes increased, decreased from 5.5 to 1.8 kg of DM for 1 kg of fertilizers. In the range of optimal dozes of fertilizers ($N_{20}P_{120}K_{160}$), each kilogram of PK fertilizers additionally gave 3.32 kg of DM of alfalfa.

The crop yield of alfalfa lies in an average correlation with the height of plants (r=0.32- 0.49). The regression equation of the dependence of plants' height (Y_5) from fertilizers corresponds to the following formula: $Y_5=73.65+5.50(NP)^{0.5}$; $R^2=0.57$. It is seen from the equation, that the change of the plants' height generally depended on the influence of nitrogen and phosphoric fertilizers. The influence of potash fertilizers was insignificant. The level of alfalfa's sprout-formation lies in close correlation with the crop yield of DM (r=0.60-0.75). The number of alfalfa's culms (Y_6) changed by years of usage in dependence on the doses of potash and nitrogen fertilizers. The regression equation has the following form: $Y_6=175.91+24.69\ N\ -62.63N^{0.5}+0.59\ (NK)^{0.5}$; $R^2=0.65$. By the third year of usage, high dozes of NK fertilizers led to a fall of the number of plants on 1 sq. m. However, the rest of plants were strenuously tillered, thus, the fall of the crop yield of DM did not occur. Significant correlation was found between the yield of alfalfa's DM and leaf - bearing (r=0.63-0.74). The dependence of plants' leaf - bearing (Y_7) from the dozes of fertilizers corresponded to the following regression equation: Y_7=33.3-1.31 N +3.7$N^{0.5}$+1.2$P^{0.5}$+3.9$K^{0.5}$; R^2=0.48. Fertilizers increased plants' leaf - bearing, which was: with $N_0P_0K_0$ – 42.3%; with $N_0P_{120}K_{160}$ – 43.5%, and with $N_{20}P_{120}K_{160}$ – 44.6%. Alfalfa is valuable as a high-protein crop. Thus, the content of raw protein (RP) in its leaves was 19.75- 30.57%. In culms this value was lower: 8.37-15.77%. The yield of protein (Y_8) depended on both the level of the yield of dry matter (r=0.83-0.89), and the doses of fertilizers, accordingly to the following regression equation: Y_8=1.16+0.07$(NK)^{0.5}$+0.08$(PK)^{0.5}$; R^2=0.65. The yield of protein generally depended on paired combinations of NK and PK fertilizers, and with higher doses increased by 1.5 times (Table 3).

Table 3. Collection of protein, (Y_8) depending on fertilizers, on average for 5 testing years.

N kg ha^{-1}	P_2O_5 Kg ha^{-1}	K_2O kg ha^{-1}		
		80	160	240
0	0			
	60	1.24	1.28	1.3
	120	1.28	1.32	1.36
	180	1.30	1.36	1.41
20	0	1.23	1.26	1.28
	60	1.31	1.38	1.42
	120	1.35	1.42	1.48
	180	1.37	1.46	1.52
40	0	1.26	1.3	1.33
	60	1.34	1.42	1.48
	120	1.38	1.47	1.53
	180	1.40	1.5	1.58
60	0	1.28	1.33	1.37
	60	1.36	1.45	1.51
	120	1.40	1.5	1.57
	180	1.42	1.53	1.61

Changing the level of the mineral nutrition, the mineral contents of alfalfa's feed also changed. The content of phosphorus in the alfalfa's leaves was 0.34-0.41%, in culms – 0.21-0.29%. The introduction of nitrogen and phosphoric fertilizers increased this value by 1.3-1.4 times. The impact of potash fertilizers on this value was insignificant.

The content of potassium in the yield of alfalfa was roughly equal in all plant's parts, and was 2.62-3.05%. Single introduction of potassium fertilizers increased the content of potassium in the feed.

The content of calcium in the leaves was 2.42-3.02%, much lower in culms (0.78-0.98%). The accumulation of calcium in alfalfa was positively influenced by NK fertilizers. The impact of potassium fertilizers was negative (R^2=0.64). The content of magnesium in the yield of alfalfa varied in the range 0.17-0.35%. Phosphoric fertilizers increased this value.

To estimate the equilibrium of mineral elements in feed, the correlation K: is importants (Ca+Mg). This correlation in DM of alfalfa was optimal – 1.28, and even with higher doses of fertilizers lay within acceptable limits. The removal of nutrients (Y_9- N; Y_{10}- P_2O_5; Y_{11}- K_2O) from the soil with the yield of alfalfa, depending on the doses of mineral fertilizers, occurred according to the following equations: Y_9=184.91+10.62 $(NK)^{0.5}$+13.62$(PK)^{0.5}$, R^2=0.85 ; Y_{10}=44.88+3.95 N+4.74 $(PK)^{0.5}$, R^2=0.64 ; Y_{11}=224.66+11.31N-7.19P+24.45 $(PK)^{0.5}$, R^2=0.80.

The nature of effect and efficiency of NPK fertilizers on the yield of DM and the removal of the key nutrients from soil are identical. Thus, the interaction of paired combinations of NK and PK fertilizers positively influenced the removal of nitrogen. The removal of phosphorus depended on the yield of DM and also from fertilizers. The amount of phosphorus, removed by alfalfa, was almost four times less than the removal of potassium and nitrogen. The removal of phosphorus increased with higher doses of phosphoric fertilizers. Single introduction of nitrogen fertilizers increased the removal of potassium, and each step of nitrogen (N_{20}) caused an increase in the

removal of potassium by 11.31kg. Single introduction of phosphoric fertilizers decreased the removal of potassium from 217.43 kg ha^{-1} (P_{60}) to 188 kg ha^{-1} with (P_{180}).
The level of the total removal of nutrients is determined generally by the crop yields of DM of alfalfa, and less depended on the chemical composition.

Conclusions

Use of NPK fertilizers is the most effective influencing factor on the crop yield of alfalfa, which is cultivated for feed. With optimal doses of fertilizers ($N_{20}P_{120}K_{160}$), the average yield of dry matter was 8.10 t ha^{-1}.
Mineral fertilizers favour the increase of the total protein. The most significant impact is shown by paired combinations of NP and PK fertilizers – with higher doses the increase of protein increased by 1.5 times.
With the application of $N_{20}P_{120}K_{160}$, alfalfa removes from the soil with the yield of dry matter 226 kg ha^{-1} of N; 55 kg ha^{-1} of P_2O_5 and 271 kg ha^{-1} of K_2O.

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LUCERNAS RAŽĪBA UN KVALITĀTE VELĒNU PODZOLĒTĀ AUGSNĒ PIE DAŽĀDIEM MINERĀLMĒSLU LĪMEŅIEM

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Rakstā apkopoti LLU aģentūras Zemkopības zinātniskā institūta lucernas 5-gadīgie pētījumu rezultāti. Pētījumi veikti velēnu podzolētā augsnē ar dažādām NPK mēslojumu devām. Minerālmēslojums būtiski palielināja lucernas zaļās masas ražu. Pie optimālā NPK mēslojuma attiecības ($N_{20}P_{120}K_{160}$) ieguva 8.10 t ha^{-1} sausnas.
Minerālmēslojums sekmēja arī kopējā proteīna ieguvi, pie paaugstinātas devas $N_{20}P_{120}K_{160}$, proteīna ieguve palielinājās 1.5 reizes.Mēslojot lucernu ar $N_{20}P_{120}K_{160}$, iegūtā lucernas sausnas raža no augsnes iznes N-226 kg ha^{-1}, P_2O_5 – 55 kg ha^{-1} un K_2O – 271 kg ha^{-1}.

THE EFFECTS OF COVER CROPS AND STRAW ON SOIL MINERAL NITROGEN DYNAMICS AND LOSSES FROM ARABLE LAND

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Abstract

Seeking to estimate the effects of biological measures – various cover crops in combination with different straw incorporation methods on the reduction of soil mineral nitrogen and nitrogen leaching complex research was conducted at the Lithuanian Institute of Agriculture‘s Joniskelis Experimental Station on clay loam *Gleyic Cambisol* during the period 2003–2005. Undersown legume crops during the post–harvest period gave the largest reduction in mineral nitrogen in the