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Yield response and element content of grass in a fertilization experiment

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Abstract

The effects of four different N, P and K supply levels and their combinations on the yield and element content of an established all-grass sward were examined in the 28-31st year of a long-term fertilization experiment set up on a calcareous chernozem soil.
During the four years the N alone gave 4.8 t/ha, while the K gave 0.5 t/ha hay surplus. N-fertilization lifted the hay mass 4-5 times compared to the N-control. The rising N, P and K supply together increased the hay yield of the control to its 7-fold. The 2nd cuts yielded less hay with higher element concentrations. The N, P, Cu content increased by 30-50% and Mo content by 200-500% in some cases. The phosphate / molibdenate and nitrate / molibdenate anion antagonism had negative effect on Mo uptake. The Cu/Mo ratio showed great variability according to the NxP interactions and cuts.
Long-term fertilization can drastically modify the element composition of the fodder, so its regular control by hay analysis seems to be reasonable.

Key words: all-grass, NPK fertilization, hay yield, mineral elements, diagnostic criteria

Introduction

Mineral fertilizers are one of the most important discoveries of modern chemistry. Well applied they maintain and even raise soil fertility, increase yields, and improve the feeding value of agricultural produce. If unwisely used, however, they can become dangerous by decreasing soil fertility as well as quality and quantity of crop yields *(Voisin 1965)*.

Schechtner (1972) in Austria established that fertilization have dual-purpose: increasing yields and developing the quality. The latter includes the domestication of the valuable grass species, as well as improving the organic and mineral composition of the fodder.

Fertilizers can modify the uptake of many elements due to antagonisms and synergisms. High Mo content dose not cause phytotoxicity, nevertheless concentration above 1-2 mg/kg can be harmful for the consumer animal in long-run *(Finck 1982, Bergmann 1992)*.
Results of a long-term fertilization experiment is summarised. This paper focuses on the effect of fertilization on yield and mineral element content of grass hay. Until 2000 several arable crops were grown in free crop rotations. The first two decades of this experiment was summarized by *Kádár (1992)*.

Material and methods

The experiment was set up at Nagyhörcsök Research Station of the RISSAC in the Mezőföld Region of Hungary. The calcareous chernozem soil of the growing site contained around 3% humus, 3–5% $CaCO_3$, 20–22% clay, 60-80 mg/kg AL (ammonuim-lactate soluble)-P_2O_5, 140-160 AL-K_2O mg/kg, 150-180 mg/kg KCl-soluble Mg in the ploughed layer according to Egner et al. (1960). The soil was originally moderately well supplied with available K, Mg, Mn, Cu and poor in P and Zn. The area was drought

sensitive with the groundwater table at a depth of 13–15 m and negative water balance of about 100 mm/yr.
The 0, 100, 200, 300 kg/ha/year N doses were divided into two halves, one was applied in autumn and the other in spring. P and K fertilization were performed with 0, 500, 1000, 1500 kg/ha P_2O_5 and K_2O load in every 5^{th} – 10^{th} year. The trial included 4N×4P×4K= 64 treatments in 2 replications, giving a total of 128 plots. The applied fertilizers were Ca-ammonium nitrate, superphosphate and potassium chloride. The experimental plots represent low, moderate, high and very high supply levels and all of their combinations, Treatments and the soluble PK contents of the soil's ploughed layer are given in *Table 1*.

Table 1. Treatments and their effects on the soluble PK-content in the plow layer.

Fertilization and soil analysis		Treatments or fertilization levels 0	1	2	3	$LSD_{5\%}$	Mean
N kg/ha/yrs		0	100	200	300	-	150
N kg/ha/30 yrs		0	3000	6000	9000	-	4500
P_2O_5 kg/ha/30 yrs		0	1500	3000	4500	-	2250
K_2O kg/ha/30 yrs		0	2500	5000	7500	-	3750
AL*-P_2O_5 mg/kg	In 2000	66	153	333	542	42	274
AL*-K_2O mg/kg	In 2000	135	193	279	390	32	249

*Ammoniumlactate soluble

From 2001 grass was grown on the whole experimental area. The mixture of 8 grass species (Meadow fescue *(Festuca pratensis)*, Tall fescue *(Festuca arundinacea)*, Perennial ryegrass *(Lolium perenne)*, Agropyron *(Agropyron cristatum)*, Red fescue *(Festuca rubra)*, Timothy *(Phleum pratense)*, Reed canarygrass *(Phalaris arundinacea)*, Cocksfoot *(Dactylis glomerata)* was established on 21^{st} September 2000 after the harvest of spinach. The dominant species was the meadow fescue with a 25% application rate.
In 2001 and 2002 two-two cuts were made at flowering stage of the dominant meadow fescue species, but in the droughty 2003 only one cut was harvested. Composite plant samples from 20 subsamples per plot were taken at harvest time for laboratory analyses. Plant samples were dried, milled and analysed for 20–25 elements with cc. HNO_3 + cc. H_2O_2 digestion and using ICP technique. N contents were measured after cc.H_2SO_4+cc.H_2O_2 digestion with the method of *Kjeldahl (1891)* modified by *ISO 11261 (1995)*. Soil composite samples from the ploughed layer out of 20 cores per plot were taken before sowing for laboratory analyses.

Results and discussion

Table 2 shows how the NPK affected the grass yields in the first four year of the experiment: at 1^{st} cuts there were no considerable effects above 100 kg/ha/year N dose, at 2^{nd} cut, however even the 300 kg/ha/year dose resulted in significant yield increase. Concerning the total yield the 200 kg/ha/year N supply proved to be optimal. While in 2001 the average N-effect at 1^{st} cut yield remains below 40% (increases yield from 4.9 to 6.8 t/ha), from the 2^{nd} cut and after at both cuts maximal N doses raise yields to 4-8-fold of the control.

No significant changes occurred at 1st cut above the satisfactory 153 mg/kg AL-P_2O_5 supply, and no P fertilization effect could be observed at 2nd cut hay. Considering the total yield this AL-P_2O_5 level could be optimal. However, the N or P overfertilization did not result in depression. The increasing K-supply levels did not affect the observed characteristics. The moderate 135 mg/kg AL-K_2O level satisfied the K demand of grass, but the excessive 390 mg/kg K_2O content did not cause any negative effect either. The grasses could efficiently use P and K pool of the soil. The 2nd cut hays yielded 58% less, than the 1st cut grass hays on an average of the years.
The 100 kg/ha/year N dose increased the yield in the 1st year 2-fold, in the 2nd year 3.9-fold, in the draughty 3rd year 5.4-fold, in the 4th year 3-fold compared to control. After the 2nd year the 2nd cut hay yield was drastically limited by N deficiency on the control plots. Increasing N, P and K levels together resulted in additional considerably yield surplus, especially in the favourably wet 1st year. The highest 48 kg surplus hay yield per 1 kg N was produced by the 100 kg/ha/year N fertilization on the plots which were also satisfactory supplied with P and K.

Table 2. Effect of different NPK supply levels on the air dry hay yield of grass by cuts, t/ha

Harvest date day/month/yr	NPK supply levels 0	1	2	3	$LSD_{5\%}$	Mean
			N treatment (average of P and K)			
23.05.2001.	4.9	6.8	6.7	6.8	0.5	6.3
09.10.2001.	1.0	2.3	3.6	3.9	0.2	2.7
Together	5.9	9.1	10.3	10.7	0.6	9.0
28.05.2002.	1.1	5.4	5.7	5.9	0.4	4.5
03.09.2002.	0.4	0.8	1.7	1.9	0.1	1.2
Together	1.5	6.2	7.4	7.8	0.4	5.7
02.06.2003.	0.8	2.9	3.4	3.2	0.2	2.6
11.05.2004.	1.2	4.1	4.3	4.4	0.2	3.5
19.07.2004.	0.4	1.5	3.1	3.4	0.2	2.1
Together	1.6	5.6	7.4	7.8	0.3	5.6
Mean	2.4	6.0	7.1	7.4	0.3	5.7
			P treatment (average of N and K)			
23.05.2001.	4.0	6.8	7.1	7.2	0.5	6.3
09.10.2001.	2.8	2.6	2.7	2.7	0.2	2.7
Together	6.8	9.4	9.8	9.9	0.6	9.0
28.05.2002.	4.1	4.9	4.5	4.6	0.4	4.5
03.09.2002.	1.3	1.2	1.2	1.1	0.1	1.2
Together	5.4	6.1	5.7	5.7	0.4	5.7
02.06.2003.	2.3	2.7	2.6	2.7	0.2	2.6
11.05.2004.	2.7	3.8	3.8	3.8	0.2	3.5
19.07.2004.	2.2	2.1	2.0	2.1	0.2	2.1
Together	4.9	5.9	5.8	5.9	0.3	5.6
Mean	4.8	6.0	6.0	6.0	0.3	5.7

The effects of the determinant N-supply levels on N, P, Cu and Mo content of the air dry hay are shown in *Table 3* as an average of the P and K treatments. The shown data also represents that increasing N supply results in higher N and Cu contents. N-fertilization increased P contents in the 1st year, but drastically decreased in the following years. Changes of Mo content reached one order of magnitude between 0.16 and 4.05 mg/kg minimum and maximum concentrations, which makes 25-fold difference. N-fertilization hindered the Mo uptake, so the nitrate/molybdate anion antagonism has influence on this well aerated calcareous chernozem soil. K content of the hay varied between 1.5-2.5% as an average depending on the K supply. The phosphate/molybdate antagonism was also notable.

Table 3. Effect of N-fertilization on the air-dry hay element content on 23rd May 2001.

Harvest date	N-fertilization, N kg/ha/yr				$LSD_{5\%}$	Mean
day/month/yr	0	100	200	300		
N%						
23.05.2001.	1.10	1.87	2.09	2.39	0.16	1.86
09.10.2001.	1.78	2.17	2.68	2.75	0.16	2.35
28.05.2002.	0.80	0.87	1.33	1.59	0.09	1.15
03.09.2002.	1.87	1.90	2.54	2.92	0.12	2.31
02.06.2003.	0.88	1.42	2.04	2.21	0.10	1.64
11.05.2004.	1.58	2.15	2.82	3.07	0.18	2.41
19.07.2004.	1.28	1.30	1.87	2.17	0.14	1.66
Mean	1.33	1.67	2.20	2.44	0.15	1.91
			P%			
23.05.2001.	0.17	0.22	0.22	0.23	0.01	0.21
09.10.2001.	0.24	0.31	0.34	0.35	0.02	0.31
28.05.2002.	0.28	0.17	0.18	0.19	0.02	0.20
03.09.2002.	0.42	0.38	0.29	0.28	0.02	0.34
02.06.2003.	0.35	0.20	0.18	0.18	0.02	0.23
11.05.2004.	0.32	0.29	0.28	0.28	0.02	0.29
19.07.2004.	0.40	0.29	0.21	0.20	0.02	0.27
Mean	0.31	0.27	0.24	0.24	0.02	0.26
			Cu mg/kg			
23.05.2001.	2.1	3.8	4.4	4.7	0.3	3.8
09.10.2001.	4.2	4.8	6.0	6.2	0.3	5.3
28.05.2002.	3.2	3.2	4.6	5.3	0.7	4.1
03.09.2002.	6.6	6.5	7.9	9.5	1.1	7.6
02.06.2003.	2.6	3.7	4.9	6.2	0.7	4.3
11.05.2004.	3.1	4.5	5.3	5.6	0.3	4.6
19.07.2004.	4.1	3.9	5.6	6.1	0.6	4.9
Mean	3.7	4.3	5.5	6.2	0.3	4.9
			Mo mg/kg			
23.05.2001.	0.21	0.20	0.18	0.16	0.02	0.19
09.10.2001.	1.60	1.02	0.80	0.84	0.12	1.06
28.05.2002.	0.48	0.38	0.37	0.32	0.08	0.39
03.09.2002.	1.00	1.30	0.99	0.92	0.14	1.05
02.06.2003.	0.58	0.51	0.51	0.45	0.06	0.51
11.05.2004.	0.81	0.64	0.52	0.42	0.09	0.60
19.07.2004.	4.05	2.79	1.21	0.91	0.31	2.24
Mean	1.25	0.98	0.65	0.57	0.15	0.86

Note: data given as a means of P and K treatments.

The Cu/Mo ratio of the 2^{nd} cut hay in the N poor treatments in 2001 dropped to about 2-4. Both the N and P fertilization inhibited the Mo uptake. Applying P and K together, the Cu/Mo ratio increased to the desirable 10-50 interval. The Cu-uptake stimulating effect of the N also contributed to this process.

Conclusions

N-fertilization was the determinant treatment. The 200 kg/ha/yr N-dose was optimal. At this site 150 mg/kg AL-P_2O_5 and AL-K_2O supply satisfied the P and K demand of the grass. Generally, the higher yields of 1^{st} cuts resulted in lower nutrient content, which showed dilution effects. Concentration of Mo on the P-oversupplied soils were only the half of the P-control treatments in average. High Mo content dose not cause phytotoxicity, nevertheless concentration above 1-2 mg/kg can be harmful for the consumer animal in long-run. In this experiment the hay is relatively rich in Mo, but poor in Cu on control plots. The Cu/Mo ratio below 10 can indicate potential/hidden Cu deficiency. The presented data indicate that Cu/Mo ratios produce more fold differences depending on years and cuts. Long term fertilization can thus considerably modify the uptake of other elements due to synergism or antagonism. Element composition of fodders should be continuously monitored.

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