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QUANTITY OF ELEMENTS LEACHED FROM THE MOUNTAIN MEADOW SOIL IN THE LONG-TERM STATIC FERTILISATION EXPERIMENT (CZARNY POTOK)

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A b s t r a c t. The present experiment studied effects of systematic, differentiated mineral fertilisation and liming on the amount of $N\text{-}NO_3^-$, K, Mg, Ca, Na ions lost from the 0-40 cm soil layer during meadow sward vegetation period as a result of leaching. The highest amount of filtrate was observed in the control object for both series, i.e. without liming and with liming. During vegetation, the level of filtrate amounted to, respectively, 224 and 213 mm on the average. The lowest pH of the lysimetric water was found in the objects fertilised with double doses of nitrate and urea. Calcium was leached from the soil to the highest degree, i.e. from 38.4 mg/lysimeter in the object unilaterally fertilised with phosphorus (the series with liming) to 231.6 mg/lysimeter on the object fertilised with 180 kg N in the form of ammonium nitrate (the series without liming). Leaching of potassium depended on the applied fertilisation with this element. The lowest loss of magnesium was found in the object unilaterally fertilised with phosphorus; respectively 12.5 mg Mg/lysimeter for the series without liming and 14.1 mg Mg/lysimeter for the series with liming.

K e y w o r d s: leaching, concentration, runoff, lysimeter, meadow soil.

INTRODUCTION

Migration of chemical components from the tilled areas deep into the soil profile has been the subject of numerous discussions and research work for a long time now. Lysimetric studies enable precise measurements of the amount of percolating water related to the cultivated plants. Investigation in this area was, among others, conducted over a hundred years ago in England [1]. Permanent grassland is the best plant cover most successfully limiting migration of fertiliser components into waters. Grassland forms a kind of a biological filter which both prevents leaching [4,5] and protects the soil against erosion and particles runoff along slopes [6].

The present work gives some preliminary results of lysimetric studies on the effect of systematic and diversified mineral fertilisation and liming on the concentration and amount of N-NO_3^-, K, Mg, Ca and Na lost as a result of leaching from the mountain meadow soil.

METHODS

Lysimetric studies were carried out on the basis of a long-term static experiment set out in 1968 on the natural mountain meadow of mat-grass (*Nardus stricta*) and red fescue (*Festuca rubra*) type with a considerable proportion of dicotyledonous plants. The experimental field was located c.a. 720 m a.s.l., at the foot of the Jaworzyna Krynicka Mount (20'8" E; 49'4" N), within the south-eastern massive of the Beskid Sądecki Mts. on the slope with 7^ogradient and NNE aspect. Average yearly precipitation over the 27 years preceding the experiment was 821 mm; average annual temperature 5.81 ^oC, while the average precipitation and temperature over the April-September period were respectively 543 mm and 11.7 ^oC [3].

The experiment was conducted on the acidic brown soil (pH KCl before the experiment was 4.4), developed from the Magura sandstone, with mechanical composition of light loam and three characteristic genetic levels: Ah (0-20 cm), ABbr (21-46 cm) and BbrC (47-75 cm). The experiment included 8 fertilised objects (Table 1) established with the method of randomised blocks in 5 replications, in two series: non-limed and limed in the 18^{th} and 27^{th} year of the experiment. Phosphorus and potassium fertilisers were applied in spring, and potassium was supplemented (half of the dose) in summer after the first cut. N-fertilisers were sown twice: 2/3 of the annual dose in spring at the start of vegetation and 1/3 of the dose several days after the first harvest.

Table 1. Design of the experimental schedule Czarny Potok

Object	Nutrient dose (kg ha^{-1})			Fertiliser form
	P	K	N	
PK	39.2	124.5	-	
PK+N_{1a}	39.2	124.5	90	ammonium nitrate
PK+N_{2a}	39.2	124.5	180	ammonium nitrate
PK+N_{1u}	39.2	124.5	90	urea
PK+N_{2u}	39.2	124.5	180	urea
N_{1a}	-	-	90	ammonium nitrate
P	39.2	-	-	-
"O"	-	-	-	-

In 1995, lysimeters were fixed in all the objects in three replications in both series (limed and non-limed). Plastic cylinders, 444.6 cm^2 big and 40 cm high, were driven into the soil in individual, fertilised objects in each field in order to limit incursion on the soil structure.

Containers placed under the lysimeters were emptied after harvesting the first and second sward cuts in 1996 and 1998. In 1997, due to technical reasons, the investigations were temporarily abandoned. The amount of washout from the lysimeters was determined and water samples were collected in which pH and concentrations of $N\text{-}NO_3^-$, K, Mg, Ca and Na were assayed.

Potassium, sodium and calcium were determined with flame photometry (FES), while magnesium using atomic absorption spectrophotometry (AAS). Nitrate nitrogen was determined colorimetrically using phenolodisulphonic acid. Mean concentrations and mean amounts of components leached during the growing period were calculated.

RESULTS

The amount of losses in the studied components leached from the soil depended on various factors, including amount of water infiltrating deep into the soil profile and individual ions concentrations in it, dry matter yield of the sward covering the soil, and the amount of components introduced through fertilisation.

In the analysed fertilising combinations on the grassland the highest average amount of washout was observed in the untreated object, characterised by the lowest yield both in the non-limed and limed series, respectively 224 and 213 mm (Table 2). Along with fertilisation causing an increase in the sward dry matter yield (Table 2), the amount of water collected in the lysimetric containers decreased. Unilateral phosphorous treatment together with PK lessened infiltration of the precipitation water in comparison with the NPK objects that were fertilised with higher nitrogen doses. They influenced loosening of the sward and enabled better water seepage deep into the soil profile. The applied unilateral phosphorus or phosphorus-and-potassium treatment caused diversification in the botanical composition, i.e. an increase in the number of grasses and legumes characterised by an increased evapotranspiration [5]. In the majority of objects, liming caused a decrease in the volume of filtrates obtained mainly due to its positive, yield creating activity (Table 2).

Reaction of the filtrates obtained in the limed series was mostly higher in comparison with the non-limed series. The lowest pH values were detected in the

Table 2. Runoff in individual objects [mm], pH of lysimetric water and dry matter yield of the sward (means for 1996 and 1998)

Object	Runoff in object (mm)		pH		Dry matter yield of sward (dt ha^{-1})	
	0Ca*	+Ca**	0Ca	+Ca	0Ca	+Ca
PK	182	174	7.29	7.31	24.6	28.5
$PK+N_{1a}$	192	192	6.62	7.06	36.8	36.1
$PK+N_{2a}$	179	188	6.45	6.06	33.5	39.3
$PK+N_{1u}$	183	189	6.74	6.94	36.6	40.0
$PK+N_{2u}$	191	187	6.59	7.10	33.0	39.1
N_{1a}	195	179	6.99	7.03	25.2	26.0
P	177	188	7.18	7.09	20.6	22.2
"O"	224	213	7.21	7.45	11.5	15.0

*non-limed series; ** limed series.

lysimetric water samples from the objects fertilised with 180 kg N+PK ha^{-1}. Such a visible decrease in comparison with "O" object, particularly in the object fertilised with 180 kg N ha^{-1} as ammonium nitrate was caused by a high concentration of NO_3^- ions of acidic character in the filtrate. Concentration of the studied ions revealed high variability between the investigated periods.

The highest concentration was observed for the Ca ions followed by NO_3^-, Mg, Na and K. The lowest concentration of Mg, Na, K and NO_3^- was noticed in the untreated objects and in the objects with unilateral phosphorus fertilisation (Table 3). PK treatment caused a release of calcium ions from the soil sorption complex and a raise in their concentration in the soil filtrate. The filtrate from the object treated with a double dose of ammonium nitrate was marked by the highest mean concentration of NO_3^-, i.e. 38.68 mg dm^{-3} in the untreated series over the analysed period (April-September 1998). Unilateral fertilisation with ammonium nitrate and the treatment against PK background caused an increase in NO_3^- concentrations in comparison with the control, which might have caused eutrophication of ground waters.

The amount of components leached with lysimetric water, which was the subject of the observations, was presented in Table 4 as average loads lost in April-September 1996 and 1998. In all the objects calcium was leached in the highest amount from the 40 cm profile - on the average between 38.4 mg/lysimeter in the object treated unilaterally with phosphorus in the limed series and 231.6 mg lysimeter in the object fertilised with 180 kg N ha^{-1} as ammonium nitrate against PK background in

Table 3. Mean concentration of elements in lysimeter waters (mg dm^{-3})

Object	Element (mg dm^{-3})									
	$N-NO_3^-$		K		Na		Ca		Mg	
	0Ca*	+Ca**	0Ca	+Ca	0Ca	+Ca	0Ca	+Ca	0Ca	+Ca
Growing season 1996										
PK	5.17	4.17	0.95	0.65	2.18	1.80	13.87	12.56	4.78	3.66
PK+N_{1a}	10.63	14.47	0.68	0.39	2.16	1.96	12.88	11.60	2.79	2.33
PK+N_{2a}	16.67	35.27	0.93	0.47	3.07	2.09	40.56	33.00	6.00	6.71
PK+N_{1u}	11.23	11.73	1.09	1.24	2.97	1.64	47.87	37.91	9.60	2.20
PK+N_{2u}	23.73	8.38	0.37	0.40	1.63	1.49	9.73	10.17	2.38	1.62
N_{1a}	13.77	16.72	0.22	0.21	1.09	1.36	5.78	7.01	0.95	2.09
P	5.05	6.52	0.39	0.66	1.24	1.37	5.25	5.90	1.24	1.46
"O"	9.23	5.88	0.29	0.55	2.44	1.50	4.91	6.24	1.20	2.41
Growing season 1998										
PK	2.90	2.86	0.90	0.47	1.89	1.27	13.75	8.91	4.88	2.68
PK+N_{1a}	23.07	17.18	0.63	0.42	2.70	2.01	15.97	21.06	5.81	5.48
PK+N_{2a}	38.68	36.32	1.74	0.62	3.38	1.80	32.43	21.42	7.60	5.40
PK+N_{1u}	7.65	5.23	0.80	1.69	2.14	1.60	22.50	16.02	2.80	5.90
PK+N_{2u}	13.31	7.06	1.64	0.29	2.60	1.29	13.72	9.55	5.36	1.77
N_{1a}	14.08	16.35	0.51	0.24	1.49	1.24	11.83	8.52	3.80	3.02
P	3.94	1.94	0.19	0.18	1.09	1.12	5.62	6.75	1.90	2.14
"O"	2.09	1.94	0.25	0.18	0.98	1.02	5.29	7.17	1.77	2.78

*non-limed series; **limed series.

the non-limed series, which corresponded to 0.8-5.2 g m^{-2}. The highest Ca leached from the soil was also confirmed by other authors [2,5,7-9].

Nitrogen is most often supplied with fertilisers, in the highest amounts on grassland. The results obtained showed that between 13.6-276 mg of this component per lysimeter (0.30-6.20 g m^{-2}) was leached. A high differentiation in the NO_3^- leaching between the investigated periods should be noted. It was due to a considerable variability in the concentration and amount of washouts from the individual combinations. A tendency to decrease nitrogen losses in the limed series was observed.

Potassium leaching depended on the fertilisation with this component. In the objects treated with 124.5 kg K ha^{-1} leaching level reached 1.5-13.1 mg/lysimeter (0.03-0.29 g m^{-2}) and was higher in comparison with the objects untreated with potassium in the successive years.

Sodium was leached in higher quantities than potassium. Its mean leaching from individual objects was least differentiated during individual vegetation periods. The limed series showed lower Na losses in all the fertilised series.

Table 4. Leaching of ions (mg/lysimeter)

Object	Element (mg/lysimeter)									
	$N-NO_3^-$		K		Na		Ca		Mg	
	0Ca*	+Ca**	0Ca	+Ca	0Ca	+Ca	0Ca	+Ca	0Ca	+Ca
	Growing season 1996									
PK	23.2	18.7	6.7	3.4	13.3	8.8	96.6	66.1	33.5	17.0
PK+N_{1a}	47.8	65.1	5.2	3.7	21.7	15.8	127.2	166.7	44.6	42.3
PK+N_{2a}	75.0	158.7	8.5	3.0	16.5	8.8	215.6	149.8	37.1	26.4
PK+N_{1u}	73.0	52.8	4.3	8.6	11.3	8.3	99.0	83.8	15.2	30.5
PK+N_{2u}	88.8	37.7	13.1	2.4	20.1	9.9	104.5	74.5	39.5	13.4
N_{1a}	61.9	75.2	3.3	1.5	9.6	7.9	74.6	56.6	22.8	19.1
P	22.7	29.3	1.1	1.2	7.2	7.4	46.0	38.4	12.8	14.3
"O"	41.5	26.4	1.6	1.5	7.8	8.1	44.8	59.0	14.4	20.3
	Growing season 1998									
PK	21.6	21.3	6.4	3.3	13.3	8.9	96.3	66.4	33.7	19.0
PK+N_{1a}	197.1	143.5	5.2	3.3	21.7	15.8	125.2	165.7	43.7	42.5
PK+N_{2a}	276.0	254.9	12.0	4.4	23.5	12.4	231.6	153.3	52.3	37.5
PK+N_{1u}	57.3	38.3	5.8	11.7	15.3	11.4	166.7	114.1	20.5	41.6
PK+N_{2u}	107.0	59.7	13.1	2.4	20.1	9.9	104.5	74.7	39.5	13.0
N_{1a}	95.0	110.9	3.6	1.7	10.4	8.6	82.1	60.7	25.8	21.0
P	27.1	13.6	1.3	1.2	7.2	7.4	46.0	38.5	12.5	14.1
"O"	17.5	16.0	1.9	1.4	7.8	8.2	44.2	59.0	14.2	21.2

*non-limed series; **limed series.

The lowest magnesium losses from the soil were found in the object unilaterally fertilised with phosphorus, respectively 12.5 mg/lysimeter (0.28 g m^{-2}) in the non-limed series and 14.1 mg/lysimeter (0.31 g m^{-2}) in the series limed in 1998 (Table 4).

CONCLUSIONS

1. Concentration of elements coming from fertilisers in the lysimetric water was characterised by a large variation in the studied vegetation periods.

2. Calcium was leached in an amount ranging from 38.4 to 231.6 mg/lysimeter, nitrogen ranged from 13.6 to 276 mg/lysimeter, magnesium from 12.5 to 52.3 mg/lysimeter, sodium from 7.2 to 23.5 mg/lysimeter, and potassium from 1.1 to 13.1 mg/lysimeter.

3. The main fertilisation treatment, particularly the use of ammonium nitrate at a dose of 180 kg ha^{-1} brought about an increase in the loss of elements from the 40 cm soil layer.

4. A single use of nitrogen fertilisation reduced the amount of leached elements.

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