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ION BALANCE IN ORDINARY COCKSFOOT SPRINKLED WITH ACID FALL AND LIMED WITH DOLOMITE

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A b s t r a c t. In the present paper the effect of simulated acid rain on the shaping of ion balance in the ordinary cocksfoot is discussed. The evaluation of this process was carried out on the basis of a three-year long field experiment performed on brown soil formed from loess. Each year in the vegetation period it was sprinkled 20 times with simulated fall with pH 7.1, 3.8 and 3.2 in the conditions of differentiated liming with dolomite.

The applied experimental factors, first of all acid fall, significantly influenced the percentage contribution of respective ions in their sums. In the non-limed objects, acid rain with pH 3.2 contributed to over double increase in percentage of SO_4^{2-} ion share in the inorganic ion sum. Simultaneously, in those objects a significant broadening of the ratio K:(Ca+Mg) value occurred, comparing to the value of this ratio in the control series. After the third year of the experiment this amounted to 2.54, i.e., the boundary value of 2.2 after which the risk of tetanygeneity of feed increases was exceeded significantly.

The liming with dolomite completely prevented the unfavourable effect of the broadening of the ratio K:(Ca+Mg) value and it partly inhibited the increase in SO_4^{2-} ion share in the dry matter of the plant tested. The carried out research allow us to state that one of the causes of the reduction of plants growing within the range of acid rain influence, may be the disturbance of the ion balance in plants.

K e y w o r d s: ion balance, ordinary cocksfoot, acid rain, lime

INTRODUCTION

Maintaining the ion balance, in the meaning of optimal ion ratio in plants, has been treated for a long time as one of the basic factors deciding about the final effect of the quantity and quality of the yield [7,18]. The desturbing of ion proportions may occur at the applying of high - not always balanced mineral fertilizing. It may occur also in the plants growing within the range of acid pollution operation. The principal negative effect of the acid imissions on the ionic composition of plants results from their indirect influence through soil. The chemical acidification of soil as the result of acid falls causes changes in the availability of nutrients and in the microbiological activity of soil and it is connected with the elution of the alkaline components and the increase in the phytotoxic substances solubility in soil [2,8,12,14,17].

Acid rainfalls also influence plants directly and it is connected with excessive uptake of ions, especially sulphates, by the assimilation organs of plants. Simultaneously, as the effect of damaging the protective layer of leaves, the elution of cations from them may occur. It pertains mainly to the cations of potassium, magnesium and calcium [2]. The change of ion distribution in soil solution in the sorptive complex and the excessive uptake of sulphates by leaves result in unfavourable ion composition of plants. We may presume that it is one of the possible causes of the reduction of yielding of the plants growing within the range of the acid rain operation.

The aim of the research presented here was to analyse the effect of simulated acid fall - in the conditions of dolomite liming and without dolomite - on the ion composition of ordinary cocksfoot.

MATERIALS

The base for the research constituted plant material obtained from the strict, three-year long field vegetative experiment. The experiment was carried out on brown soil formed from loess, with the grain-size distribution of silt. The soil had light acid reaction, very high available phosphorus content, high potassium availability and medium available magnesium content. The testing plant was ordinary cocksfoot (*Dactylis glomerata L.*) of Motycka variety, harvested three times during the vegetation period. The experiment was carried out in the years 1989-1991 with the method of completely randomized blocks. It comprised three variable factors (the pH of simulated fall, dolomite dose, years) on three levels. The scheme of the experiment comprised 9 objects in 4 replications:

1. S_0Ca_0
2. S_1Ca_0
3. S_2Ca_0
4. S_0Ca_1
5. S_1Ca_1
6. S_2Ca_1
7. S_0Ca_2
8. S_1Ca_2
9. S_2Ca_2.

S_0 - sprinkling with water the pH of which was 7.1 (± 0.1);
S_1 - sprinkling with acid solution of pH 3.8 (± 0.05);
S_2 - sprinkling with acid solution of pH 3.2 (± 0.05);
Ca_0 - without liming;
Ca_1 - dolomite liming according to 0.5 Hh - 0.85 t CaO 100 % ha^{-1};
Ca_2 - dolomite liming according to 1 Hh - 1.7 t CaO 100 % ha^{-1}.

Pollution background: natural fall reaction - 5.3 pH (4.9-6.2), $S\text{-}SO_4$ content (mg S dm^{-3}) - 3.05 (2.30-4.75).

The surface of the experimental field was 4 m^2. Liming was carried out once before the sowing of cocksfoot according to the scheme of the experiment. Ground dolomite with total alkalinity 45 % CaO was used for liming.

The NPK fertilizing in the form of NH_4NO_3, $Ca(H_2PO_4)_2$ and 60 % KCl was applied every year in all the objects in the following amounts: 180 kg N, 26 kg P and 100 kg K ha^{-1}. Each year during the vegetation, in the period from 15.05 to 25.09, plants were sprinkled according to the enclosed scheme once a week. During the three years 60 sprinkling were performed, 20 times a year.

In one treatment 12.5 mm of fall (50 dm^3/ 4 m^2) was supplied, during one vegetation period it amounted to 250 mm. Water taken from a deep well with pH 7.1 was used for sprinkling. The solutions with pH 3.8 and 3.2 were prepared by mixing water with sulphuric acid in the suitable proportion. The solution having pH 3.8 contained 12 mg S dm^{-3}, and that having pH 3.2 - 24 mg S dm^{-3}. Thus with the simulated falls 30 (S_1) and 60 (S_2) kg S ha^{-1} in the form of H_2SO_4 was introduced yearly into soil. The average amount of sulphur coming from natural rainfalls during the experiment amounted to 14.7 kg S $ha^{-1}year^{-1}$.

The plant material was taken from single fields for the mineral composition analysis three times each year during the harvesting of the each outgrowth of cocksfoot. After the mineralization of the plant material in H_2SO_4 with the addition of H_2O_2 the following contents were determined:

- phosphorus - colorimetrically with vanadium-molybdenum method,
- potassium and calcium with flame photometry method,
- magnesium, manganese and iron with the method of atomic absorption spectrometry.

After the extraction of plant material 2 % CH_3COOH with the addition of active carbon, the sodium content was determined with flame photometry method as well as chlorine and sulphate sulphur content nephelometrically. In the water extract from the ground plant material after the protein precipitation with trichloroacetic acid the content of the following components was determined:

- ammonium nitrogen - colorimetrically with Nesler's method;
- nitrate nitrogen colorimetrically with phenoldisulphonic acid.

The results of the analyses were expressed in mmol (±) 1 000 g^{-1} (so far 'me').

The cation sum (Σ K) was calculated according to the theoretical bases concerning the ion balance in plants, i.e. by adding ions K^+, Na^+, NH^+, Ca^{2+} and Mg^{2+}. The sum of inorganic anions (Σ An. inorg.) constitutes the sum of NO_3-, Cl^-, H_2PO_4- and $SO_4$2-.

RESULTS

The data presenting the influence of the reaction of simulated rainfall and dolomite dose on ionic composition of ordinary cocksfoot are presented in Table 1. The analysis of the results shows that cations are comparatively stable in all the experimental objects. The plants sprinkled with the fall which had pH 3.8 and 3.2 had only slightly higher values of cation sums comparing to these values in the controll combination. The increase in cation sums by several percent in these objects resulted mainly from the increase of potassium and sodium content in dry mass of ordinary cocksfoot. In the objects without dolomite, sprinkled with pH 3.2 fall, a significant decrease of calcium and magnesium amount was noted in comparison with the contents of those ions in the dry mass of plants from the control objects.

In the above objects, the amount of calcium decreased from 31.4 to 25.4 mmol (±)100 g^{-1}, and that of magnesium from 15.6 to 13.2 mmol(±)100 g^{-1}. In the relative values this decrease, in case of calcium, amounts to 19.1 % and in case of magnesium to 15.4 %.

The sums of inorganic anions were differentiated to a much greater extent (Table 1). Depending on the experimental object Σ An inorganic amounted from 44.0 to 67.8 mmol (±) 100 g^{-1}.

The highest content of inorganic anions had the plants sprinkled with the fall the pH of which was 3.2. It resulted first of all from the three-fold increase in sulphate content in the dry matter of plants from these objects comparing to the values of these ions noted in control objects.

The experimental factors to a great extent influenced the forming of the proportion K:(Ca+Mg), (Table 2). The greatest disturbance of this proportion occurred in the experimental series without dolomite, sprinkled with the fall the pH of which had been 3.2. In the dry matter of plants from the discussed here objects - as the result of limiting the magnesium and calcium uptake - the value of the proportion K: (Ca+Mg) broadened to a great extent comparing to the control objects. The highest value of the ratio of calcium to calcium and magnesium sum was achieved in the third year of the experiment.

It amounted to 2.54, i.e., it significantly exceeded the value 2.2 accepted as the boundary one, over which the risk of the fodder tetanygeneity increases. Dolomite liming improved to a great extent the relation between potassium, calcium and magnesium in the dry matter of the test plant. The average value K: (Ca+Mg) for the level Ca_1 amounted 1.55 and for level Ca_2- 1.44.

Table 1. Influence of simulated rain and liming on the ionic composition of cocksfoot grass [mmol (±) 100 g^{-1}) - the average data from three years

Treatments	Cations						Anions				
	K^+	Na^+	Ca^{2+}	Mg^{2+}	NH_4^+	ΣK	NO_3^-	$H_2PO_4^-$	Cl^-	SO_4^{2-}	ΣAn inorg.
S_0Ca_0	71.4	3.9	31.4	15.6	7.8	130.1	6.4	10.6	25.9	6.2	49.1
S_1Ca_0	77.8	4.8	31.9	16.4	7.1	138.0	5.7	11.0	25.4	10.0	52.1
S_2Ca_0	83.9	5.2	25.4	13.2	9.3	137.0	9.3	11.0	28.2	19.3	67.8
S_0Ca_1	69.6	3.5	32.9	17.3	7.1	130.4	5.7	10.6	24.0	5.6	45.9
S_1Ca_1	72.4	3.9	34.4	18.0	6.4	135.1	5.7	10.6	22.3	8.1	46.7
S_2Ca_1	82.4	4.8	30.4	15.6	7.8	141.0	7.8	10.6	24.2	15.0	57.6
S_0Ca_2	67.8	3.5	33.9	17.3	7.1	129.6	5.7	10.3	21.4	5.0	42.4
S_1Ca_2	70.6	3.9	35.4	18.1	6.4	134.4	5.0	10.6	20.3	8.1	44.0
S_2Ca_2	74.2	4.3	31.9	16.4	7.8	134.6	7.1	11.0	22.3	14.3	54.7

Table 2. Influence of simulated rain and liming with dolomite on the formation of the molar ratio (+) K: (Ca+Mg) value in the dry mass of cocksfoot grass

Treatments / Years		Ca_o			Ca_1			Ca_2		$\bar{x}$ years
	S_o	S_1	S_2	S_o	S_1	S_2	S_o	S_1	S_2	
1989	1.53	1.45	1.77	1.43	1.30	1.51	1.34	1.25	1.45	1.45
1990	1.79	1.77	2.42	1.64	1.69	2.07	1.58	1.54	1.90	1.82
1991	1.40	1.71	2.54	1.30	1.34	1.63	1.23	1.27	1.34	1.54
$\bar{x}$ - S				1.47	1.48	1.86				
$\bar{x}$ - Ca		1.82			1.55			1.44		
$\bar{x}$ - SxCa	1.57	1.64	2.25	1.46	1.44	1.74	1.39	1.36	1.58	
$\bar{x}$ LxS 1989				1.43	1.33	1.58				
1990				1.67	1.67	2.13				
1991				1.31	1.44	1.86				
$\bar{x}$ LxCa 1989		1.58			1.41			1.35		
1990		1.99			1.80			1.68		
1991		1.88			1.42			1.30		

LSD (p=0.01); S, Ca, L = 0.048; S x Ca; S x L; Ca x L = 0.112; S x Ca x L = 0.224.

Table 3. Influence of simulated rain and liming with dolomite on the formation of proportional share of SO_4^{2-} in the total of inorganic anions in the dry mass of cocksfoot grass

Treatments / Years		Ca_o			Ca_1			Ca_2		$\bar{x}$ years
	S_o	S_1	S_2	S_o	S_1	S_2	S_o	S_1	S_2	
1989	13.4	21.0	28.1	11.4	19.1	27.0	12.4	19.8	25.8	19.8
1990	105.	18.2	28.3	9.7	15.7	26.1	9.2	17.0	28.0	18.1
1991	15.1	19.3	30.8	13.7	18.0	27.1	14.0	18.7	27.1	20.4
$\bar{x}$ - S				12.2	18.5	27.6				
$\bar{x}$ - Ca		20.5			18.6			19.1		
$\bar{x}$ - SxCa	13.0	19.5	29.0	11.6	17.6	26.7	11.9	18.5	26.9	
$\bar{x}$ LxS 1989				12.4	20.0	26.9				
1990				9.8	17.0	27.4				
1991				14.3	18.7	28.3				
$\bar{x}$ LxCa 1989		20.8			19.1			19.3		
1990		19.0			17.2			18.1		
1991		21.7			19.6			19.9		

LSD (p=0.01); S, Ca, L = 0.66; S x Ca, S x L, Ca x L = 1.53; S x Ca x L = 3.05.

The consequence of the differentiation of sulphates in the dry matter of ordinary cocksfoot as the effect of the applied experimental factors is the significant influence of these factors on the percentage contribution of $S\text{-}SO_4$ in Σ An. inorganic formation (Table 3). In the control objects (S_0Ca_0) the percent share of sulphate ions in the sum of inorganic ions amounted on the average -13 %. The highest increase of the sulphates share occurred in the effect of sprinkling the plants with the simulated acid fall in the non-limed series. Cocksfoot from these objects which had been sprinkled with the fall with pH 3.8 had 19.5 % share of $S\text{-}SO_4$ in Σ An inorganic. The application of the fall with pH 3.2 was connected with the increase in the percentage contribution of sulphates to 29 %, i.e., over double in comparison to these ions share in the control objects. Dolomite liming of plants to a limited degree influenced the decrease of proportional sulphates share in the sum of inorganic anions in the dry content of ordinary cocksfoot.

DISCUSSION

The sprinkling of ordinary cocksfoot with the simulated rain influenced, to a great degree, the changes in its chemical composition. Their range was the highest after sprinkling with the rain with pH 3.2 in the non-limed objects. Among cations the influence of the acid rain in this experimental series manifested mainly by the decrease in magnesium and calcium concentration in the dry matter of ordinary cocksfoot. The amounts of exchangeable ions in the dry mass of the tested plant were correlated with their amount in soil [8]. This correlation testifies to the strict connection between ion saturation in the sorption complex of soil and the ionic composition of plants [4,6,7]. It also testifies to the fact that the negative influence of acid rains on the environment of plants is connected with the indirect effect on them through soil. As the result of these dependencies, in the dry matter of ordinary cocksfoot from non-limed objects but sprinkled with the fall with pH 3.2, the lowering of calcium content by 19.1 % occurred and the lowering of magnesium by 15.4 % in comparison to the amount of these ions in the control objects. The decrease in magnesium content in the forest trees - most probably because of long-term effect of acid rains - is the most frequently signalled cause of the occurrence of the disturbances in the growth and development of trees.

Among the inorganic anions the acid rain effect manifested first of all in a significant increase of sulphate sulphur in the dry matter of plants. In the majority of papers [5,7,10,12,16] pertaining to the effect of SO_2 on the chemical composition of plants, higher amounts of sulphates in their organs are noted as the result of this gas presence. Slightly smaller amounts of sulphate sulphur were noted in the dry matter of plants from the limed objects which may results from the so-called 'dilution of component'. It is well known phenomenon which accompanies achieving high yielding of plants [11]. Dolomite liming may also have influenced the dicrease in sulphate content in the dry matter of ordinary cocksfoot directly. Known are the papers [1,13] in which it is stressed that the increase in calcium and especially magnesium ion contents in the sorption complex limits the uptake of sulphates by plants.

The changes in content of several ions were connected with the disturbance of ion proportions between cations and anions. In the experimental series S_2Ca_0 the share of sulphates in Σ An inorganic increased almost two times as compared with the control series S_0Ca_0. As the result of lowered uptake of calcium and magnesium the value of the ratio K:(Ca+Mg) broadened in these objects to the values over which the risk of feed tetanygeneity increases [15].

The analysis of the obtained results allows to presume that the described changes in the ion proportion in cations and anions may be one of the causes of the yield reduction of cocksfoot which grows within the range of acid pollution effect. Such an interpretation is confirmed partly by the author's earlier papers pertaining to the effect of SO_2 and acid rain on some elements of ion balance in plants [7,9].

Dolomite liming influenced the maintanance of the proper ratios between potassium, calcium and magnesium and slightly decreased the percentage contribution of sulphates in Σ An inorganic.

As it results from literature [2,3], liming constitutes the basic measure counteracting the acidification of soil in the condition of acid emission effect in case of agricultural ecosystems, as well as forest and water ones.

CONCLUSIONS

1. Watering the plants with simulated rain with pH 3.2 caused a significant decrease in magnesium and calcium content and three-fold increase in sulphates in the dry matter of ordinary cocksfoot comparing to the control objects.

2. The changes in the content of the several ions were connected with the disturbance of ion ratios between cations and anions. In the experimental series sprinkled with the rainfall the pH of which was 3.2 the sulphates share in the Σ An inorganic increased over two times comparing to the share of those ions in the control series. Simultaneously - in the effect of uptaking calcium and magnesiumby the plants - the value of the ratio K:(Ca+Mg) broadened over the boundary value 2.2 which increases the risk of feed tetanygeneity occurring.

3. Dolomite liming influenced maintaining the right proportions between potassium, calcium and magnesium and slightly decreased the percentage contribution of sulphates in the Σ An inorganic.

4. Unfavourable changes in ion proportions between cations and anions may be one of the causes of the reduction the yielding of the plants growing within the range of acid pollution effect.

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W pracy określono oddziaływanie symulowanego kwaśnego deszczu na kształtowanie się równowagi jonowej w s.m. kupkówki pospolitej. Ocenę przeprowadzono w oparciu o trzyletnie badania polowe, wykonane na glebie brunatnej wytworzonej z lessu. Każdego roku w okresie wegetacji stosowano 20 deszczowań symulowanym opadem o pH 7.1, 3,8 i 3.2 w warunkach zróżnicowanego wapnowania dolomitem.

Zastosowane czynniki doświadczalne, przede wszystkim zaś kwaśny opad, wpłynęły w istotnym stopniu na zróżnicowanie procentowego udziału poszczególnych jonów w ich sumach. W obiektach nie wapnowanych kwaśny deszcz o pH 3.2 przyczynił się do ponad dwukrotnego wzrostu procentowego udziału jonów SO^{2-} w sumie anionów nieorganicznych. Jednocześnie w obiektach tych wystąpiło znaczne rozszerzenie wartości K:(Ca+Mg) w porównaniu z wartością tego stosunku w serii kontrolnej. Po trzecim roku badań wartość ta wynosiła 2.54 zatem przekroczona została wyraźnie wartość graniczna 2.2, powyżej której wzrasta ryzyko tężyczkogenności paszy. Wapnowanie dolomitem całkowicie zapobiegało niekorzystnemu rozszerzaniu się wartości stosunku K:(Ca+Mg) oraz częściowo zahamowało wzrost udziału jonu SO^{2-} w s.m. rośliny testowej. Przeprowadzone badania upoważniają do stwierdzenia, że jedną z przyczyn redukcji plonu roślin rosnących w zasięgu oddziaływania kwaśnych opadów może być zachwianie relacji jonowych w roślinach.

S ł o w a k l u c z o w e: równowaga jonowa, kupkówka pospolita, kwaśny opad, wapnowanie.