ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1992 z. 398, 13-18

THE INFLUENCE OF DIFFERENT MOISTURE LEVELS AND OF SATURATION WITH EXCHANGEABLE CATIONS OF SOIL ON THE BIOMASS AND BASIC ELEMENTS OF IONIC BALANCE OF SPRING BARLEY AND OATS

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A b s t r a c t. Using basic pot experiments and chemical analyses of soils and plants, this study sought to determine the effect of soil moisture and soil saturation with cations on the yield of spring barley and oats and on the state of ionic balance in the plants. It was found that an increase in soil moisture positively affected the quantity of spring barley mass but negatively affected that of oats mass. In conditions of higher soil moisture, there was a higher uptake of non-organic anions and a lower uptake of cations by the plants. Saturation of the soil with base cations above 60 % positively affected the quantity of both spring barley and oat mass.

INTRODUCTION

The state of ionic balance in plants depends on mineral nourishment [1-6,10] and on the conditions of growth and cultivation of the plants. The chemical properties of the soil should also be taken into account, as should the activity of the soil solution, the valency of the cations and the anions, and the sorption capacity. Climatic factors, and above all temperature and moisture, exert a considerable influence on the formation of the ionic balance in plants [8,9,12]. The soil moisture level favours the absorption of cations over inorganic anions, leading to an increase in the different totals of cations (C) and inorganic anions (A), thereby qualifying the amount of organic anions (C-A), [7, 11, 13].

METHODS

The investigations were carried out on the basis of pot experiments in a vegetation hall over a period of two years with spring barley, and over the next two years with oats.

The pots were filled with 5.4 kg of podzol soil at pH 4.2 formed from silts of origin. The schema encompassed three levels of moisture, i.e., 14 %, 23.5 %, and 33 % v/v. At each level of moisture, the saturation of the sorption complex of the soil was differentiated with cations producing the following treatments: 0 - control, CaO - calcium oxide applied in the amount 7.06 g/pot (according to 1 hydrolytic acidity), CaO+MgO (1:1) - applied in the amount of 6.05 g/pot, and $MgSO_4$ - in the amount 15.41 g $MgSO_4 \times 7 H_2O$ per pot.

In all the pots, NPK fertilization was uniformly applied in these amounts: 0.150 g N in the form NH_4NO_3; 0.065 g P in the form $CaHPO_4 \times 2 H_2O$; and 0.150 g K/kg of soil in the form of KCl.

The root mass and the above ground parts of the indicator plants were harvested in three phases, following the Feekes scale: 7, 10.54, and 11.4.

In the tests with mature barley and oats in the earlier phases of growth, a full complement of ions was identified; in the grain and straw, the value of the make-up of basic minerals was identified.

In the mineralization obtained by using concentrated sulphuric acid with the addition of perhydrol, the following were identified: total nitrogen using the Kjeldahl method; phosphorus colorimetrically identified using the vanadium-molibdenum method; potassium and calcium in a flame photometry; magnesium, colorimetrically identified with titan yellow, and aluminium colorimetrically identified with aluminium. In the extract of 2 % of the plant material, using a flame photometry, sodium,chlorides and sulphates were colorimetrically identified in a solution of acetic acid with the addition of activated carbon. In the aqueous extract from the ground plant material, NH^+-N was colorimetrically identified with Nesler reagent, and NO_3^- N with phenolodisulphone acid after the precipitation of the proteins in a solution of trichloroacetate acid.

In the soil, it was possible to identify the value of the different cations by testing an extraction of its growth in a solution of 1 M CH_3COONH_4 dm^{-3} at pH 7. In the cation filtrate, Ca^{2+}, Na^+, and K^+ were identified by the photometric lead material, whereas Mg^{2+} was identified by the AAS method. The value of the hydrogen ions tested matches the hydrolytic acidity.

The basic elements of the structure of the crop and the indicators of the ionic balance in the spring barley and the oats were investigated with regard to the level of moisture and saturation of the soil with cations. The following was revealed in two levels of the value of the cations in the sorption complex of the soil: H^+ 0-10 and 25-40 mmol H(+)/kg; Ca^{2+} 0-25 and 26-50 mmol Ca^{2+}/kg; Mg^{2+} 0-10 and 11-20 mmol Mg^{2+}/kg and the degree of soil sorption with bases (V), to 60 % and above 60 %. From the different totals of cations (C) and inorganic anions (A), the amount of organic anions (C-A) was calculated.

RESULTS

The root mass and the above-ground part of the indicator plants

Independent of the degree of soil saturation with alkaline cations, the level of moisture between 14 % and 33 % that was tested did not cause any change in the mature barley root mass, but it did increase the growth rate of its above-ground mass. If, however, the value of the H^+ cations in the soil increased to over 25 mmol (+)/kg, for both lower and higher levels of soil moisture, then the root mass and the above-ground parts of the plant were subject to a decrease.

In the case of oats, throughout all levels of soil moisture, both the root as well as the above-ground parts of the plant decreased.

The increase in the saturation of the soil sorption complex with alkaline cations at each level of moisture caused an increase in the root mass and the above-ground parts in both plant experiments. Only a crop of seed oats under these conditions did not undergo any major changes, although its growth rate was positively influenced by a greater value of Mg^{2+} in the soil (Tables 1, 2).

Elements of ionic balance

The moisture level of the above-mentioned soil, of which 14 % was tested independently of the exchangeable cations, increased to the point where it equalled the lowest cation amount (C) and an amount of organic anions (C-A), and up to the highest amount of inorganic anions (A), in both indicator plants. However, the barley and the oats reacted differently to the value of $Ca^{2+}$and Mg^{2+} under various moisture level conditions. The level of soil moisture in the barley caused an increase in the value of Ca^{2+} and a drop in Mg^{2+}, while in the oats a differing value of these elements did not occur (Tables 3, 4).

Similar tendencies in the state of the elements of ionic balance under discussion were to be found in the plants taken from soil with a greater H^+ ion value. The increase in the soil of the value of Ca^{2+},

Table 1. Dry mass of barley above-ground parts and roots at growth stage 10.54 according to Feekes scale (in g/10 plants)

Dry mass (in g/10 plants)	Soil moisture (%)	Content of exchangeable cations (mmol (+) / kg of soil)						Degree of soil saturation base		Average mass from object
		H^+		Ca^{2+}		Mg^{2+}		%		(g)
		0-10	25-40	0-25	26-50	0-10	11-20	< 60	> 60	
Above-ground parts of plants	14	44.6	26.4	26.4	34.3	29.5	31.2	23.8	34.3	30.3
	23.5	49.3	37.1	37.1	41.3	36.5	41.8	34.7	41.3	39.2
	33	47.9	38.6	38.6	43.8	40.7	42.0	34.9	43.8	41.2
Grain	14	30.4	22.5	22.5	27.9	23.5	26.9	19.2	28.5	25.2
	23.5	31.1	23.3	31.1	32.4	28.3	35.1	31.8	32.4	31.7
	33	31.1	30.5	30.5	36.6	30.1	39.4	32.4	36.2	33.6
Straw	14	27.0	21.1	21.1	25.4	22.6	24.0	19.5	23.4	23.3
	23.5	26.2	18.5	26.2	26.9	26.5	26.6	26.8	20.1	26.6
	33	31.4	30.5	30.5	36.1	30.9	37.2	31.0	36.1	33.3
Roots	14	4.4	2.8	2.9	3.7	3.1	3.5	2.7	3.6	3.3
	23.5	3.9	3.4	3.4	3.9	3.5	3.7	3.6	3.9	3.6
	33	3.5	2.7	2.7	3.5	2.8	3.6	2.6	3.5	3.1

Table 2. Dry mass of oat above-ground parts and roots at growth stage 10.54 according to Feekes scale (in g/10 plants)

Dry mass (in g/10 plants)	Soil moisture (%)	Content of exchangeable cations (mmol (+) /kg of soil)						Degree of soil saturation base		Average mass from object
		H^+		Ca^{2+}		Hg^{2+}		(%)		(g)
		0-10	25-40	0-25	26-50	0-10	11-20	<60	>60	
Above-ground parts of plants	14	33.8	25.7	27.9	42.9	26.7	32.5	25.3	43.2	29.0
	23.5	32.7	30.3	23.0	35.0	23.6	36.2	30.0	42.3	31.6
	33	22.6	18.9	15.9	28.8	17.5	24.0	14.2	24.6	20.8
Grain	14	33.1	32.2	32.5	33.3	31.2	35.0	32.0	33.0	32.9
	23.5	38.0	33.5	38.6	40.4	33.3	38.2	33.5	38.2	35.8
	33	28.2	27.2	26.6	28.3	26.5	31.4	28.2	31.4	27.1
Straw	14	29.0	27.6	28.0	28.4	26.9	29.8	20.0	28.4	20.3
	23.5	31.6	28.7	25.7	32.8	28.4	31.9	20.7	31.6	30.2
	33	30.2	25.2	25.6	31.2	24.9	30.4	25.2	30.2	27.7
Roots	14	3.9	2.7	3.2	4.4	3.0	3.6	2.7	3.9	3.3
	23.5	23.5	3.8	3.4	3.2	3.6	2.8	4.4	3.4	3.7
	33	1.3	0.5	0.8	1.0	0.4	1.5	0.6	1.3	1.1

Table 3. Some elements of ionic balance in barley at growth stage 10.54 according to Feekes scale as related to the soil moisture and saturation of the soil cations

Some elements of ionic balance	Soil moisture (%)	Content of exchangeable cations (mmol (+)/kg of soil)						Degree of soil saturation base (%)	
		H^+		Ca^{2+}		Mg^{2+}			
		0-10	25-40	0-25	26-50	0-10	11-20	<60	>60
Sum of cations (C)	14	150.4	119.9	119.9	150.4	146.2	124.1	119.9	150.4
	23.5	131.7	116.8	116.8	131.7	142.1	106.4	116.8	131.7
	33	134.3	134.3	134.3	134.2	152.1	116.4	134.3	134.2
Sum of inorganic anions (A)	14	53.1	52.1	52.1	53.1	55.3	49.9	52.1	53.1
	23.5	49.2	52.7	52.7	119.2	63.6	48.7	52.7	49.2
	33	49.1	66.2	66.2	49.1	56.7	58.6	66.2	49.1
Amount of organic anions (C - A)	14	93.8	67.8	67.8	93.8	87.4	74.2	67.8	93.8
	23.5	72.1	64.1	64.1	72.1	78.4	57.7	64.1	72.1
	33	85.2	68.1	68.1	85.2	95.4	57.9	68.1	85.2
Content of Ca^{2+}	14	42.1	29.3	29.3	42.1	47.0	24.3	29.3	42.1
	23.5	37.5	32.3	32.3	37.5	47.2	22.6	32.3	37.5
	33	45.7	49.2	49.2	45.7	58.8	36.1	45.2	45.7
Content of Mg^{2+}	14	15.2	14.2	14.2	15.2	49.6	24.5	14.2	15.2
	23.5	11.9	12.5	12.5	11.9	3.6	20.7	12.5	11.9
	33	7.0	11.7	11.7	7.0	3.2	15.5	11.7	7.0

Table 4. Some elements of ionic balance in oat at growth stage 10.54 according to Feekes scale as related to the soil moisture and saturation of the soil cations

Some elements of ionic balance	Soil moisture (%)	Content of exchangeable cations (mmol (+)/kg of soil)						Degree of soil saturation base (%)	
		H^+		Ca^{2+}		Mg^{2+}			
		0-10	25-40	0-25	26-50	0-10	11-20	<60	>60
Sum of cations (C)	14	197.2	194.6	194.6	197.2	214.5	172.3	194.6	197.2
	23.5	196.2	176.7	176.7	195.0	197.1	175.8	176.7	196.0
	33	195.7	184.7	184.7	195.7	205.3	175.1	184.7	195.7
Sum of inorganic anions (A)	14	43.9	52.2	52.2	43.9	48.4	43.9	52.2	43.9
	23.5	47.3	52.3	52.2	49.9	46.6	52.7	53.0	47.3
	33	48.7	56.2	56.2	48.7	53.1	51.0	56.2	48.7
Amount of organic anions (C - A)	14	153.3	142.4	142.4	143.0	166.1	143.0	142.4	153.3
	23.5	148.8	124.7	124.7	145.3	150.5	123.1	124.7	148.8
	33	146.9	128.5	128.5	146.9	152.1	123.3	128.5	146.9
Content of Ca^{2+}	14	92.2	76.4	76.4	79.0	102.4	79.0	76.4	92.2
	23.5	95.8	69.5	69.5	89.1	104.6	55.7	69.5	95.8
	33	93.2	73.4	73.4	93.2	107.8	59.1	73.7	93.2
Content of Mg^{2+}	14	16.5	20.5	20.5	26.1	8.0	26.1	40.9	16.5
	23.5	20.5	20.6	20.6	34.2	7.8	34.0	20.6	20.5
	33	22.6	22.1	22.1	22.6	9.3	35.4	22.1	22.6

and the resulting increase in its degree of saturation with alkalines under a lower moisture level, caused in the barley an increase in the total number of cations, the number of inorganic anions, and the content of Ca^{2+}; it did not, however, cause any difference in the sum of inorganic anions and the Mg^{2+} content. In the barley harvested from soil with a higher moisture level and higher alkaline cations, the total for the cations did not experience any differentiation; the amount of organic cations, in a similar way to those taken from plants with a lower moisture level, resulted in an increase, and the total of the inorganic as well as the Ca^{2+} value, and most especially the Mg^{2+} value, underwent a decrease. A similar pattern for the formation of ionic balance elements was observed, though not without exceptions. It should be noted that both in the mature barley as well as in the oats taken from soil with a higher level of Mg^{2+}, not counting its moisture level, every ionic balance element (with the exception of the value of Mg^{2+}) resulted in a decrease.

CONCLUSIONS

In general, we may conclude that:

1. Independent of the level of soil saturation with cations, the direction and range of the influence of water-oxygen conditions on the plant mass depended to a greater degree on the plant species. The mature barley reacted to the increased soil moisture with an increased mass growth rate, while the oats underwent a reduction.

2. The increased soil moisture exerted an influence in the majority of cases on the reduction of the C cations total, the amount of C-A organic anions, and the increase in the A inorganic anions total, both in the mature barley as well as in the oats.

3. The increase in soil saturation with alkaline cations to over 60 % had an influence which was of more benefit to the mature barley mass and oats and to their basic ionic balance elements than the increase in the level of soil moisture from 14 % to 33 % in the plants tested.

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WPŁYW ZRÓŻNICOWANEJ WILGOTNOŚCI I WYSYCENIA KATIONAMI WYMIENNYMI GLEBY NA MASĘ ORAZ PODSTAWOWE ELEMENTY RÓWNOWAGI JONOWEJ JĘCZMIENIA JAREGO I OWSA

Na podstawie badań wazonowych i analizy chemicznej gleby i roślin określono zależności pomiędzy wilgotnością i wysyceniem gleby kationami oraz plonowaniem i stanem równowagi jonowej jęczmienia jarego i owsa. Wzrost wilgotności wpłynął pozytywnie na wielkość biomasy jęczmienia jarego i negatywnie na masę owsa. W warunkach wyższej wilgotności gleby rośliny pobierały więcej anionów nieorganicznych A i mniej kationów C. Wysycenie gleby kationami zasadowymi ponad 60 % wpływało korzystnie na wielkość masy jęczmienia jarego.