

EFFECT OF NITROGEN AND POTASSIUM FERTILISATION ON THE CONTENT OF IONS IN THE SOIL SOLUTION

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Abstract

The aim of the present research was to evaluate whether or not, and to what extent, exclusive mineral fertilisation affects the content of water-soluble ions determining the soil salinity. The soil was sampled from the arable layer of a multi-year field experiment carried out in 1974-2007. The research involved differentiated nitrogen fertilisation (factor I, $n=3$) and potassium fertilisation (factor II, $n=4$). The content of water-soluble ions was defined in water extract, in the soil to water ratio of 1:5; cations K^+ , Na^+ , Ca^{2+} were determined with the method of emission spectrometry and Mg^{2+} – with atomic absorption. Anions were analysed with the argentometric (Cl^-) and nephelometric (SO_4^{2-}) methods. In addition, electrolytic conductivity (R) was tested with the conductometric method, based on which the salt concentration in the solution (C) and the ionic strength (I) were calculated. The present results were statistically verified. The prolonged application of intensive nitrogen and potassium fertilisation (32 years) significantly differentiated the content of cations: K^+ , Na^+ , Ca^{2+} and Mg^{2+} as well as anions: Cl^- and SO_4^{2-} in soil solution. The contents of K^+ , Na^+ , Ca^{2+} , Mg^{2+} in the soil solutions differed and fell within the range of (mean value) 0.136-0.507 (0.281) K^+ , 0.398-0.555 (0.472) Na^+ , 1.2.192 (1.350) Ca^{2+} and 0.211-0.365 (0.272) Mg^{2+} $mmol(+)\cdot kg^{-1}$. The highest nitrogen dose significantly limited the concentration of SO_4^{2-} in the soil solution, while the different doses of potassium did not result in such significant changes in the concentration of the above ions. The content of chlorine ions in the soil solution did not depend significantly on differentiated nitrogen and potassium fertilisation. No effect of the long-term mineral fertilisation on soil salinity was noted.

Key words: fertilisation, ions, salt indicator.

WPŁYW NAWOŻENIA AZOTEM I POTASEM NA ZAWARTOŚĆ JONÓW W ROZTWORZE GLEBOWYM

Abstrakt

Celem badań była ocena, czy i na ile wyłączne nawożenie mineralne wpływa na zawartość wodnorozpuszczalnych jonów decydujących o zasoleniu gleby. Próbki gleby pobrano z warstwy ornej wieloletniego doświadczenia polowego, które prowadzono w latach 1974-2007. W badaniach stosowano zróżnicowane nawożenie azotem (I czynnik, $n=3$) i potasem (II czynnik, $n=4$). Zawartość wodnorozpuszczalnych jonów oznaczono w wyciągu wodnym, stosunek gleby do wody jak 1:5; kationy K^+ , Na^+ , Ca^{2+} metodą spektrometrii emisyjnej, a Mg^{2+} metodą absorpcji atomowej, aniony – metodą argentometryczną (Cl^-) oraz nefelometryczną (SO_4^{2-}). Oznaczono także przewodnictwo elektrolityczne (R) metodą konduktometryczną, na podstawie którego obliczono stężenie soli w roztworze (C) i moc jonową (I). Wyniki badań opracowano statystycznie. Wieloletnie (32 lata) stosowanie intensywnego nawożenia azotem i potasem istotnie różniowało zawartości kationów: K^+ , Na^+ , Ca^{2+} i Mg^{2+} oraz anionów: Cl^- i SO_4^{2-} w roztworze glebowym. Zawartość K^+ , Na^+ , Ca^{2+} , Mg^{2+} w roztworze glebowym wynosiła odpowiednio: 0,136-0,507 średnio (0,281), 0,398-0,555 średnio (0,472), 1-2,192 średnio (1,350), 0,211-0,365 średnio (0,272) $mmol(+)\cdot kg^{-1}$. Największe dawki azotu istotnie ograniczały koncentrację SO_4^{2-} w roztworze glebowym, natomiast zróżnicowane dawki potasu nie miały tak znaczącego wpływu. Zawartość jonów chlorowych w roztworze glebowym nie zależała istotnie od różnicowanego nawożenia azotem i potasem. Nie stwierdzono wpływu długofałistnego nawożenia mineralnego na zasolenie gleby.

Słowa kluczowe: nawożenie, jony, zasolenie.

INTRODUCTION

Soil is a live formation, which shows a specific state of equilibrium between biotic and abiotic processes which determine its fertility. The concentration of respective components in the soil solution varies in time and is conditioned by many factors, both natural and anthropogenic, including brine solutions and industrial wastewater, salts applied for clearing roads from snow and mineral fertilisers (MURAWSKA 2005, KASZUBKIEWICZ et al. 2003). These factors can determine soil fertility and quality. They can also condition soil salinity, which manifests chemical degradation of environment (CAMPEBELL et al. 1989, ŁABĘTOWICZ 1995). Soil salinity in seaside soils and soils in the close vicinity of brine has been researched thoroughly (KUCHARSKI 1995, PRACZ 2005). Nonetheless, there is little evidence pertaining to long-term effect of mineral fertilisers, except for natural fertilisation and liming, on the content of cations and anions in soil, which determine its salinity (CAMPEBELL et al. 1989, ŁABĘTOWICZ, RUTKOWSKA 2001, RUTKOWSKA et al. 2009). With that in mind, the present research has been performed to find out whether or not, and if so, to what extent, long-term nitrogen and potassium fertilisation affects the content of water-soluble ions determining the soil salinity.

MATERIAL AND METHODS

The research material consisted of soil sampled from the arable layer of long-term field experiment carried out in 1974-2007. Differentiated nitrogen (factor I, $n=3$) and potassium (factor II, $n=4$) fertilisation was applied (Table 1). Detailed experimental data are provided are reported by MURAWSKA (2005).

Table 1

The application of mineral fertilisers

Fertilisation level (mean/year in kg·ha ⁻¹)						
N			K			
N ₁	N ₂	N ₃	K ₀	K ₁	K ₂	K ₃
80	160	250	0	50	106	155

The following determinations were made on the soil samples: content of water-soluble ions in water extract, at the soil-to-water ratio of 1:5; cations K⁺, Na⁺, Ca²⁺ using emission spectrometry and Mg²⁺ with atomic absorption and anions applying the argentometric (Cl⁻) and nephelometric (SO₄²⁻) methods. Additionally, electroconductivity (R) with the conductometric method was determined, based on which the salt concentration in the solution (C) and ionic power (I) were calculated from the formulas: C=640·R (mg·dm⁻³) and I=0.013·R (mol·dm⁻³). The results were statistically verified with analysis of variance according to the model compliant with the experimental design, using Tukey's test to evaluate the significance of differences.

RESULTS AND DISCUSSION

The soil phase is highly sensitive to changes in the chemical composition is the soil solution. These changes are a resultant of numerous factors, including fertilisation (ŁABĘTOWICZ, RUTKOWSKA 2001, MURAWSKA 2005). Excessively intensive mineral fertilisation increases the content of salts easily soluble in soils. Under Polish climatic conditions, fertiliser salts dissolved by precipitation waters penetrate deep into soil due to the process of migration and increase the degree of mineralization of soil- and groundwater. The present results suggest that the examined nitrogen fertilisation regime significantly determined the content of water-soluble forms of magnesium and sodium, while potassium fertilisation affected the content of potassium, magnesium and calcium (Table 2). They also depended significantly on the interaction of the factors researched. The content of K⁺, Na⁺, Ca²⁺, Mg²⁺ in the

Table 2

Content of water-soluble ions in the soil samples ($\text{mmol} (+) \cdot \text{kg}^{-1}$)

Potassium					
Fertilisation level	K ₀	K ₁	K ₂	K ₃	Mean
N ₁	0.136	0.207	0.225	0.507	0.269
N ₂	0.179	0.324	0.282	0.340	0.256
N ₃	0.202	0.212	0.369	0.486	0.317
Mean	0.172	0.214	0.292	0.444	0.281
LSD for I – ns, II – 0.052, IIxI – 0.090, IxII – 0.089					
Magnesium					
N ₁	0.255	0.323	0.241	0.225	0.261
N ₂	0.324	0.211	0.218	0.255	0.252
N ₃	0.300	0.233	0.216	0.365	0.303
Mean	0.293	0.256	0.259	0.281	0.272
LSD for I – 0.034, II – 0.039, IIxI 0.067, IxII – 0.062					
Calcium					
N ₁	2.192	1.275	1.000	1.017	1.371
N ₂	1.542	1.050	1.033	1.173	1.200
N ₃	1.400	1.617	1.500	1.400	1.479
Mean	1.711	1.314	1.178	1.197	1.350
LSD for I – n.s., II – 0.409, IIxI 0.708, IxII – 0.665					
Sodium					
N ₁	0.441	0.455	0.398	0.477	0.443
N ₂	0.505	0.497	0.405	0.501	0.477
N ₃	0.467	0.437	0.555	0.528	0.496
Mean	0.471	0.462	0.453	0.520	0.472
LSD for I – 0.048, II – n.s., IIxI – 0.109, IxII – 0.097					

soil solution varied and fell within the range of (the mean): 0.136-0.507 (0.281) K⁺, 0.398-0.555 (0.472) Na⁺, 1-2.192 (1.350) Ca²⁺ and 0.211-0.365 (0.272) Mg²⁺ mmol(+). kg^{-1} .

The content of sulphate ions (VI) in the soil solution was evidently higher than that of cations and the concentration of chlorine ions fell within the concentration range of K⁺, Mg²⁺ and Na⁺ (Table 3). The highest nitrogen dose significantly limited the concentration of SO₄²⁻ in the soil solution, while the potassium doses did not result in such significant changes in the concentration of the above ions. The interaction of nitrogen and potassium

Table 3

Content of anions in the soil samples ($\text{mmol} (+) \cdot \text{kg}^{-1}$)

Sulphate (VI)					
Fertilisation level	K ₀	K ₁	K ₂	K ₃	mean
N ₁	11.60	14.00	13.69	13.90	12.78
N ₂	12.56	12.06	16.12	13.86	13.11
N ₃	15.87	9.91	8.31	11.58	10.97
Mean	13.34	11.98	12.69	13.11	12.29
LSD for I – 2.13. II – n.s. IIxI – 4.72. IxII – 4.27					
Chlorides					
Fertilisation level	K ₀	K ₁	K ₂	K ₃	mean
N ₁	0.31	0.31	0.27	0.27	0.29
N ₂	0.43	0.35	0.39	0.41	0.40
N ₃	0.46	0.40	0.50	0.46	0.46
Mean	0.40	0.35	0.39	0.38	0.38
LSD for I – 0.05. II – n.s. IIxI – n.s. IxII – n.s.					

fertilisation significantly differentiated the content of sulphates in the soil solution. This effect was particularly strong when the highest nitrogen dose was applied (N₃). The highest amount of sulphate (VI) was found in the soil without potassium fertilisation, which – irrespective of its rate – significantly limited their concentration. This effect could have been due to a competitive effect of chlorine ions entering soil with potassium fertilisers as well as an increased uptake of sulphates by plants well supplied with nitrogen.

The content of chlorine ions in the soil solution ranged from 0.27 to 0.50 $\text{mmol}(-) \cdot \text{kg}^{-1}$ (on average 0.38 $\text{mmol}(-) \cdot \text{kg}^{-1}$) and it did not depend significantly on differentiated nitrogen and potassium fertilisation (Table 3).

The percentage share of the analysed cations in the pool increased in the following order: Mg²⁺<K⁺<Na⁺<Ca²⁺ (Figure 1a). Of the determined anions, sulphates (VI) made up as much as 97% (Figure 1b).

The measure of soil salinity is based on the electroconductivity of water-soil extracts, which in the analysed samples was on average 53.3 $\mu\text{S} \cdot \text{cm}^{-1}$ (Table 4). It was much lower than the threshold value assumed for saline soils, which is 4 $\text{mS} \cdot \text{cm}^{-1}$ (PRACZ 2001, HULISZ 2007, CORWIM, LESCH, 2005). That parameter can be applied to evaluate other indicators of soil salinity, for example salt concentration in the extract or the ionic power (Table 4), which likewise remained at a very low level in the present research.

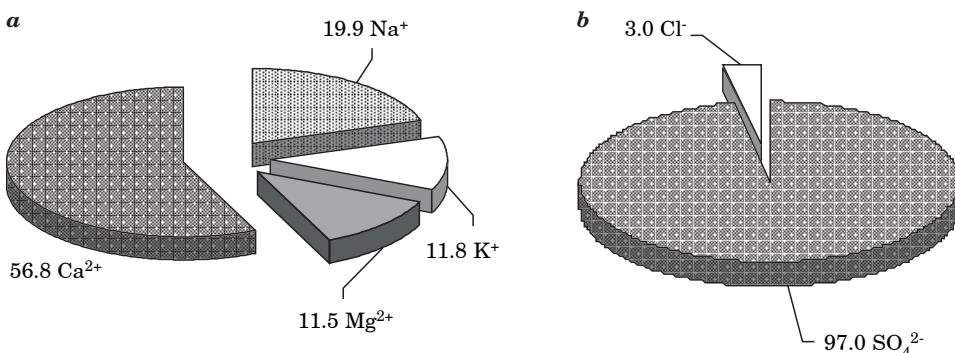


Fig. 1. Percentage share of the cations (a) and anions (b)

Table 4

Salt indicator

Parameter		Range	Mean	Median
Electroconductivity	$\mu\text{S} \cdot \text{cm}^{-1}$	35.2 - 85.90	53.30	49.21
Salt concentration	$\text{mg} \cdot \text{dm}^{-3}$	20 694 - 55 003	34 136	31 495
Ionic power	$\text{M} \cdot \text{dm}^{-3}$	0.420 - 1.117	0.693	0.640

CONCLUSIONS

The present results were statistically verified. The prolonged application of intensive nitrogen and potassium fertilisation (32 years) significantly differentiated the content of cations K⁺, Na⁺, Ca²⁺, Mg²⁺ and anions Cl⁻, SO₄²⁻, although it did not lead to soil salination. It can therefore be stated that salination of the analyse soils was not directly caused by the long-term fertilisation, which under the climatic conditions prevailing in Poland can only increase the degree of mineralization of soil- and groundwater.

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