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Effect of irrigation and anions introduced in the form of magnesium salts on selected biochemical quality indices of sandy soil

Wpływ nawadniania oraz anionów wprowadzonych w formie soli magnezowych na wybrane biochemiczne wskaźniki jakości gleby lekkiej

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Abstract

In this study, the effect of irrigation and anions introduced in the form of $Mg(NO_3)_2$, $MgCO_3$ and $MgSO_4$, which are biochemical indices of soil quality. Two laboratory experiments using complete randomisation were performed. First, one-factor experiment was carried out in triplicate. In this experiment, anion introduced with magnesium salt was the factor. The second experiment also was carried out in triplicate. In this experiment, the soil column for laboratory investigations of irrigated soil was used, anion introduced with magnesium salt was the first factor, and thickness of the soil layer was the second factor. The prepared material was irrigated nine times. In soil samples, the activity of dehydrogenases, proteases, alkaline phosphatase, amylase, and catalase was assayed. Based on these results, the biological index of fertility and enzyme activity number were calculated.

Anions introduced in the form of magnesium salts as well as irrigation caused significant changes in the enzymatic activity of sandy soil. The highest changes of dehydrogenases activity, alkaline phosphatase, protease and amylase were found in the soil with the addition of the carbonate anion. Calculated biochemical indicators of soil quality, biological indicator of fertility and enzyme activity index were increased after the introduction of the magnesium salt, especially in the thickness of soil 0–10 cm.

Streszczenie

W przeprowadzonych badaniach analizowano wpływ anionów pochodzących z $Mg(NO_3)_2$, $MgCO_3$ oraz $MgSO_4$, a także nawadniania na biochemiczne wskaźniki jakości gleby. Założono dwa doświadczenia laboratoryjne metodą kompletnej randomizacji. Doświadczenie pierwsze jednoczynnikowe w trzech powtórzeniach, gdzie czynnikiem był anion towarzyszący kationowi magnezu. Doświadczenie drugie dwuczynnikowe w trzech powtórzeniach założono wykorzystując urządzenie kolumnowe do laboratoryjnych badań gleby z nawadnianiem, gdzie pierwszym czynnikiem był anion towarzyszący kationowi magnezu, natomiast drugim miąższość warstwy gleby. Tak przygotowany materiał deszczowano dziewięciokrotnie. W próbkach glebowych oznaczono aktywność dehydrogenaz, proteaz, fosfatazy alkalicznej, amylazy oraz katalazy. Na podstawie uzyskanych wyników obliczono biologiczny wskaźnik żyzności oraz enzymatyczny wskaźnik aktywności.

Wprowadzone aniony w postaci soli magnezu, jak i nawadnianie spowodowały istotne zmiany aktywności enzymatycznej gleby lekkiej. Największe zmiany aktywności dehydrogenaz, fosfatazy alkalicznej, proteaz oraz amylazy stwierdzono w glebie z dodatkiem anionu węglanowego. Obliczone biochemiczne wskaźniki jakości gleby: biologiczny wskaźnik żyzności oraz enzymatyczny wskaźnik aktywności uległy podwyższeniu po wprowadzeniu wszystkich soli magnezu, co szczególnie uwidoczniło się w glebie z miąższości 0–10 cm.

1. INTRODUCTION

Magnesium is a scarce element in most Polish soils. This element is very mobile and easily leached into the deeper layers of the soil profile. So it should be used regularly. In general, in more sandy and acidic soils, the leaching of magnesium is the highest. In contrast to potassium, it is also easily leached from the clay soil. Symptoms of magnesium deficiency in plants, especially in the early stages of development, are evidence of this process (Hagen and Howard 2011).

A useful basis for assessing the soil quality is considered to be its biological activity (Bielińska 2009, Piotrowska and Koper 2010). Schloter et al. (2003) report that the soil quality is mainly shaped as a result of transformation of the organic matter, primarily associated with the microorganisms, enzymes, and the rate of change biogeochemical carried in the circulation of the elements. The enzymatic activity thus reflects the direction and the nature of biogeochemical processes, as well as all the basic transformation of biology and physicochemical properties of soils (De la Paz Jimenez et al. 2002). In studies of biological properties of soils, enzymes from the class of oxidoreductases and hydrolases (Brzezińska 2002) are generally measured.

The aim of this study was to assess the effect of anions used in the form of magnesium salts and irrigation on enzymatic activity in sandy soil.

2. MATERIAL AND METHODS

Experiments were carried out on brown-rust from the Agricultural Experimental Station in Lipnik. The soil samples were collected from the arable-humus (0–10 cm). Soil material was characterised by the grain size distribution of loamy sand (PTG 2009) with granulometric composition of 76% sand (ø 2.0–0.05 mm), 21% silt (ø 0.05–0.002 mm) and 3% clay particles (ø<0.002 mm). The value of pH measured in 1 M KCl was 5.30. Organic carbon was determined with the Tiurin method and its content in soil was equal to 7.95 g•kg^{-1}. Magnesium salt doses were determined on the basis of marked value of hydrolytic acidity – they were calculated in order to balance 1 mol H(+)•kg^{-1} of soil. The value of hydrolytic acidity was 2.85 cmol(+)•kg^{-1}.

Two laboratory experiments in complete randomisation were carried out. In the first one, a simple-factor experiment in triplicate, the factor was the anion in magnesium salts: I – O, II – $MgCO_3$, III – $MgSO_4$, and IV – $Mg(NO_3)_2$. Soil samples treated with magnesium salts were stored as dried. Doses of magnesium salts per 1 kg of soil were: I – 0, II – 1.20 g $MgCO_3$, III – 1.71 g $MgSO_4$, and IV – 2.11 g of $Mg(NO_3)_2$.

In the second-factor experiment, the soil column was used for laboratory investigations of irrigated soil – PO No. 54427 (Wojcieszczuk 1996). It was carried out in three replications. In this experiment, the first factor was the anion in magnesium salts: I – O, II – $MgCO_3$, III – $MgSO_4$, and IV – $Mg(NO_3)_2$, while the second factor was the soil layer thickness: 0–10, 10–20, and 20–30 cm. The columns were filled with 4 kg of soil material previously mixed with the calculated dose of the magnesium salt I – 0, II – 4.80 g $MgCO_3$, III – 6.84 g $MgSO_4$, and IV – 8.44 g of $Mg(NO_3)_2$. The prepared material was irrigated nine times. During irrigation, 8600 cm^3 of deionised water, which is soaked by gravity, was used for each column. After the irrigation, the soil material from the columns was separated into three layers. The obtained soil material was analysed biochemically. In the soil layer with a thickness of 20–30 cm there was no enzymatic activity. So, in this paper these results were omitted.

In soil samples, enzyme activities were determined by spectrophotometry, using UV-1800 Shimadzu: dehydrogenases [EC 1.1.1.x] – DHA, according to Thalmann (1968); protease [EC 3.4.21.19] – PR, according to Ladd and Butler (1972); alkaline phosphatase [EC 3.1.3.1] – Pal, following Tabatabai and Bremner (1969) procedure in Margesin (1996) modification; and amylase [EC 3.2.1.1] – AM, according to Pachloy and Rice (1973). Using manganometric method, catalase [1.11.1.6] – CAT activity was determined (Johnson and Temple 1964).

On the basis of the enzymatic activity soil quality indices were calculated:

– biological index of fertility: BIF = (1.5•DHA + 100 *k*•CAT) / 2, where *k* is a proportionality factor = 0.01 (Stefanic et al. 1984)
– enzymatic activity number: EAN = 0.2•(0.15•DHA + CAT + 1.25•10^{-2}•Pal + 4•10^{-2}•PR + 6•10^{-4}•AM) (Beck 1984).

All assays were performed in triplicate. The obtained results of soil enzymatic activity were analysed statistically. To assess the significance of differences, Tukey's test was used at a significance level α = 0.05.

3. RESULTS AND DISCUSSION

Fertilisers used in agriculture could affect the physical, chemical and biochemical properties of soil (Wongpokhom et. al. 2008, Wojcieszczuk and Wojcieszczuk 2009). They may also influence the excessive accumulation in the soil solution cations: Ca^{2+}, Mg^{2+}, Na^+, and K^+ and the anions NO_3^-, SO_4^{2-}, CO_3^{2-}, and Cl^- (Siddikee et al. 2011). Increased ion content can significantly affect the activity of soil enzymes (Telesiński 2012).

Soil treatment of a magnesium salt: Mg(NO3)2, MgSO4, and $MgCO_3$ caused significant changes in the soil enzymatic activity. These changes in non-irrigated soils were significantly dependent on the anion introduced with the magnesium salts. The highest stimulation of dehydrogenases, catalase, alkaline phosphatase, and protease activities was noted in soil treated with $MgCO_3$, respectively: 25, 14, 5 and 16% compared with control soil. However, amylase activity was increased to the greatest extent (9%) after the introduction of $Mg(NO_3)_2$ (Table 1). Similar relationships were shown in irrigated soil in both the depth of 0–10 and 10–20 cm. Results showed the highest activation of all enzymes was assayed after the treatment with $MgCO_3$ (Table 2). Similarly, as in the irrigated soil, the highest stimulation was observed in dehydrogenases activity (37%). This confirms the results obtained by El-Shinnawi and El-Shimi (1981). They found that among anions introduced into the soil together with cations Ca^{2+}, Mg^{2+}, Na^+, and K^+, the highest stimulated dehydrogenases, phosphatase and urease was caused by anion CO_3^{2-}.

Comparing the changes of soil enzymatic activity, depending on the soil layer, there was a significant decrease with depth, which confirms numerous studies (Guwy et al. 1999, Bielińska 2005, Telesiński et al. 2010).

Calculated soil quality indices also showed that in the non-irrigated and irrigated soil, the highest increase in BIF and EAN was caused with the addition of magnesium carbonate (Fig. 1). Wojcieszczuk and Wojcieszczuk (2009) found that changes in the chemical properties of soils are significantly dependent on the anion introduced with calcium cations. The impact on the test soil most preferably was calcium carbonate, which reduced the acidity of the soil and reduced the activity of exchangeable aluminum. Use of sulfate (VI) and nitrate (V) of calcium did not affect the value of the true hydrolytic acidity (Hh) of soil, but still increased the total exchange

Table 1. Changes of enzyme activities in non-irrigated soil treated with $Mg(NO_3)_2$, $MgCO_3$, and $MgSO_4$

Enzyme	Control	$Mg(NO_3)_2$	$MgCO_3$	$MgSO_4$	$LSD_{0.05}$
Dehydrogenases [μg TPF•(g d.w. soil•h)$^{-1}$]	2.08	2.20	2.60	2.31	0.143
Catalase [% O_2•(g d.w. soil•3 min)$^{-1}$]	1.87	1.95	2.14	2.08	0.067
Alkaline phosphatase [μmol p-NP•(g d.w. soil•h)$^{-1}$]	11.87	12.24	12.51	12.21	0.382
Protease [μg Tyr•(g d.w. soil•2 h)$^{-1}$]	22.28	25.35	25.79	24.78	0.847
Amylase [mg glucose•(g d.w. soil•16 h)$^{-1}$]	2.18	2.38	2.20	2.31	0.104

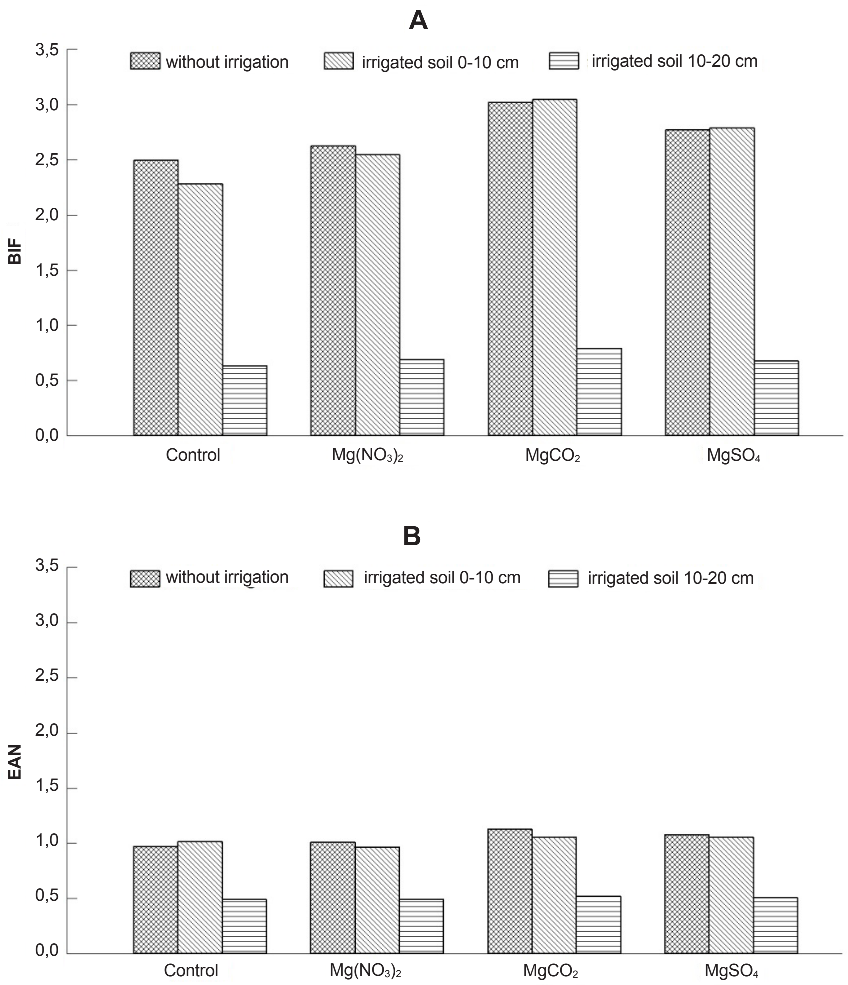

Fig. 1. Changes of biological indices of quality in soil after irrigation and treatment with $Mg(NO_3)_2$, $Mg(NO_3)_2$, and $MgSO_4$; A – biological index of fertility (BIF), B – enzymatic activity number (EAN)

Table 2. Changes of enzyme activities in irrigated soil treated with $Mg(NO_3)_2$, $Mg(NO_3)_2$, and $MgSO_4$

Depth – B	Fertilisation – A				
	Control	$Mg(NO_3)_2$	$MgCO_3$	$MgSO_4$	Average
Dehydrogenases [μg TPF•(g d.w. soil•h)$^{-1}$]					
0–10 cm	1.89	2.27	2.60	2.44	2.30
10–20 cm	0.74	0.81	0.93	0.79	0.82
Average	1.31	1.54	1.76	1.61	1.56
$LSD_{0.05}$	A = 0.179 B = 0.248 A × B = 0.287 B × A = 0.276				
Catalase [% O_2•(g d.w. soil•3 min)$^{-1}$]					
0–10 cm	1.73	1.89	2.19	1.92	1.93
10–20 cm	0.16	0.17	0.19	0.17	0.17
Average	0.94	1.03	1.19	1.04	1.05
$LSD_{0.05}$	A = 0.092 B = 0.147 A × B = 0.188 B × A = 0.193				
Alkaline phosphatase [μmol p-NP•(g d.w. soil•h)$^{-1}$]					
0–10 cm	11.51	11.87	12.48	12.18	12.01
10–20 cm	8.97	8.38	9.86	9.08	9.04
Average	10.24	10.12	11.17	10.63	10.52
$LSD_{0.05}$	A = 0.332 B = 0.401 A × B = 0.443 B × A = 0.462				

cont. Table 2.

Protease [µg Tyr•(g d.w. soil•2 h)$^{-1}$]					
0–10 cm	23.53	22.08	23.97	24.12	23.42
10–20 cm	11.83	11.81	12.37	12.21	10.05
Average	17.68	16.94	18.17	18.16	16.73
$LSD_{0.05}$	A = 0.634 B = 0.803 A × B = 0.824 B × A = 0.863				
Amylase [mg glucose•(g d.w. soil•16 h)$^{-1}$]					
0–10 cm	2.08	2.42	2.46	2.23	2.30
10–20 cm	0.92	0.94	0.99	0.87	0.93
Average	1.50	1.68	1.72	1.55	1.61
$LSD_{0.05}$	A = 0.118 B = 0.120 A × B = 0.138 B × A = 0.141				

capacity (T). In addition, the influence of sulphate (VI) and nitrate (V) of calcium in the soil test did not change significantly the activity of exchangeable aluminum although at the same time, and the value of the active acidity (Hc). This is also reflected in our study, which reported an increase in biological indicators of soil quality after the introduction of $MgSO_4$ and Mg $(NO_3)_2$, but not as significant as the addition of $MgCO_3$.

Calculated indices found that they reduce with depth of the soil. Similar results were obtained by Telesiński et al. (2010). The values of the biological indicator in agricultural soils are formed at the level of 0.16–7.22 (Levi-Minzi et al. 2002) and the enzymatic activity index 1–4 (Beck 1984).

4. CONCLUSION

1. Anions introduced in the form of magnesium salts as well as irrigation caused significant changes in the enzymatic activity of a sandy soil.
2. The highest changes of activity of dehydrogenases, alkaline phosphatase, protease, and amylase were found in the soil treated with carbonate anion.
3. Calculated biochemical indices of soil quality: biological index of fertility and enzymatic activity number were increased after the introduction of the magnesium salt, which is especially seen in the soil of thickness 0–10 cm.

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