ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

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EFFECT OF FERTILIZATION WITH ENTEC-26 AND AMMONIUM NITRATE ON THE CHANGES IN SELECTED CHEMICAL SOIL PROPERTIES AFTER CARROT CULTIVATION

WPŁYW NAWOŻENIA ENTEC-26 I SALETRĄ AMONOWĄ NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

Abstract: In the research carried out in 2004–2005 with carrot cultivation the following combinations were applied: 1 – Control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 +70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; where 35 + 35, 70 + 70 and 105 + 105 kg N · ha^{-1} denote nitrogen doses applied for presowing fertilization and top dressing, respectively. In case of ENTEC-26 [a fertilizer with nitrification inhibitor, 3,4-dimethylpyrazol phosphate (DMPP)], in both years of the research a tendency of lowering the content NH_4-N in both analyzed layers of the soil with increasing nitrogen dose was observed. These interrelations were not noted in case of fertilization with ammonium nitrate. In the individual years of the experiments nitrogen fertilization had a dissimilar effect of the content of NH_4-N, NO_3-N, Cd, Cu, Pb and Zn after the cultivation and percentage change of these chemical properties in the soil layers of 0–30 cm and 30–60 cm in relation to the values measured prior to carrot cultivation. No significant effect of applied fertilization on soil reaction (pH) was noted.

Keywords: nitrogen leaching, nitrification inhibitor, 3,4-dimethylpyrazol phosphate (DMPP), heavy metals

One of the negative consequences of using chemical nitrogen fertilizers is the process of leaching NO_3-N from soil into groundwater [1]. This process is less intensive when applying fertilizers containing reduced forms of N (NH_4-N and NH_2-N) present in physiologically acid fertilizers. However, in the soil process of nitrification these forms are oxidized (after initial transformation from NH_2-N into NH_4-N) into NO_3-N form, which is susceptible to leaching [2]. One possibility of stabilizing reduced forms of N in soil is the use of nitrification inhibitors [3–5]. A negative aspect of applying physiologically acid fertilizers may be a decrease in soil pH value what contributes to an increase of the content of heavy metals forms available for plants [6].

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The aim of our research was to determine the effect of doses and time of ENTEC-26 application [7.5 % NO_3-N, 18.5 % NH_4-N, 13 % SO_4-S and nitrification inhibitor 3,4-dimethylpyrazol phosphate (DMPP)] in comparison with fertilization with ammonium nitrate on the changes in selected chemical properties of soil after carrot cultivation.

Material and methods

The field experiment on carrot, 'Kazan F_1' cv., cultivation was conducted in 2004–2005 at Trzciana, each year on a different site within a single soil complex owned by a single horticultural farm. The carrot plants were cultivated in a three-year crop rotation composed of sugar beets 1st year, winter wheat 2nd year and carrot 3rd year. The seeds were sown on 24th April 2004 and 30th April 2005. The experiments were arranged in a split-plot design in four replications. The experiments comprised of the following treatments: 1 – Control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; where 35 + 35, 70 + 70 and 105 + 105 kg N · ha^{-1} denote nitrogen doses applied for presowing fertilization and top dressing, respectively.

Soils samples from two layers: 0–30 cm and 30–60 cm were taken in spring before the experiment outset as well as during carrot harvesting (24th September 2004 and 8th September 2005). During carrot harvesting soil samples were collected for each nitrogen fertilization treatment. Methods of soil analysis included assessment of: soil texture using Casagrande method modified by Pruszynski, organic matter content with Tiurin method modified by Oleksynowa and pH in H_2O determined potentiometrically (1 : 2, soil : H_2O volumetric ratio). Contents of NH_4-N and NO_3-N forms of mineral nitrogen in soil (after extraction with 0.03 mol · dm^{-3} CH_3COOH) were determined using the microdistillation method. Contents of Cd, Cu, Pb and Zn (after extraction with 0.01 mol · dm^{-3} $CaCl_2$) were determined by AAS technique.

The results of physical chemical properties of soil prior to carrot cultivation are presented in Table 1, while climatic conditions during the experimental period are shown in Table 2.

Table 1

Physical and chemical characteristics of soil layers 0–30 and 30–60 cm prior to experiment in 2004–2005

Characteristics	2004		2005	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm
Soli texture class	Silty clay	Silty clay	Silty clay	Silty clay
Organic matter [%]	2.20	1.33	2.26	1.50
pH_{H2O}	7.80	7.75	7.55	7.70
NH_4-N [mg · dm^{-3}]	12.3	10.5	21.0	7.0
NO_3-N [mg · dm^{-3}]	33.3	35.0	33.3	21.0
Cd [mg · kg^{-1}]	0.09	0.07	0.18	0.06
Cu [mg · kg^{-1}]	3.35	3.75	0.23	0.11
Pb [mg · kg^{-1}]	2.22	2.23	0.13	0.03
Zn [mg · kg^{-1}]	8.11	5.05	1.08	0.16

Table 2

Meteorological data for the region where experiment was conducted (Rzeszow-Jasionka, Poland – 50°05′ N, 21°98′ E) during the period of experiment

Specification for growth period and years	Year 2004			Year 2005		
	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]
April	8.7	72.5	237.1	9.1	48.4	189.9
May	12.3	40.9	242.1	13.9	105.1	264.5
June	16.5	64.3	254.4	16.8	109.6	296.6
July	18.5	179.6	272.5	19.8	109.1	291.5
August	18.4	98.8	256.0	17.5	123.9	224.2
September	13.3	22.5	210.9	14.8	62.4	242.0
Mean for growth period	14.6	79.8	245.5	15.3	93.1	251.5
Sum for growth period	—	558.4	1718.5	—	651.6	1760.2
Mean for year of study*	8.5	742.0	2012.0	8.3	774.0	2106.0
Mean for 1951–2005	8.1	642	1846.4**	—	—	—

* Data for Rzeszow-Jasionka Poland from Concise Statistical Yearbook of Poland (2000, 2001, 2002, 2003, 2004, 2005, 2006), Polish Central Statistical Office, Warsaw, Poland; ** Sunshine only for 2001–2005.

Obtained results were verified statistically with the ANOVA module of 'Statistica 8.0 PL' for $p < 0.05$. The significance of differences was computed with Duncan test. A more detailed description of the experiments together with the results concerning the effect of fertilization on the quantity and quality of carrot yield have been published previously [7–9].

Results and discussion

It should be emphasized that with comparatively similar physical chemical characteristics of soil in both years of the experiments: soil texture class, content of organic matter and pH value (Table 1), higher rainfall in 2005 (especially in May, June, August and September) when compared with 2004 (Table 2) could have been the reason for lower soil content of NH_4-N and NO_3-N. What is more, that weather conditions could have contributed to demonstrated differences in size of change in the content of these forms of nitrogen in the layers 0–30 and 30–60 cm of soil after cultivation in comparison with initial values (Fig. 1 and 2). The results of analyses of NH_4-N and NO_3-N content in soil after cultivation, as well as size of changes in the content of both form of nitrogen in 0–30 and 30–60 cm soil layers before the outset of carrot cultivation demonstrate that the efficiency of DMPP nitrification inhibitor on stabilizing ammonium form of nitrogen in soil depended both on fertilizer dose and the course of climatic conditions during cultivation, with a particular emphasis on the amount and distribution of rainfall (Table 2). In 2005, unlike in 2004, there were no significant differences noted in the content of NH_4-N in both layers of soil.

Contrary to theoretical premises, in each year of fertilizing with ENTEC-26, there was a tendency of lowering the content of NH_4-N in both analyzed layers of soil along with increasing nitrogen dose accompanied by consequently higher dose of nitrification inhibitor. These interactions were not observed in case of fertilization with ammonium nitrate (Fig. 1). In 2004, the soil fertilized with ammonium nitrate as 70 + 70 and

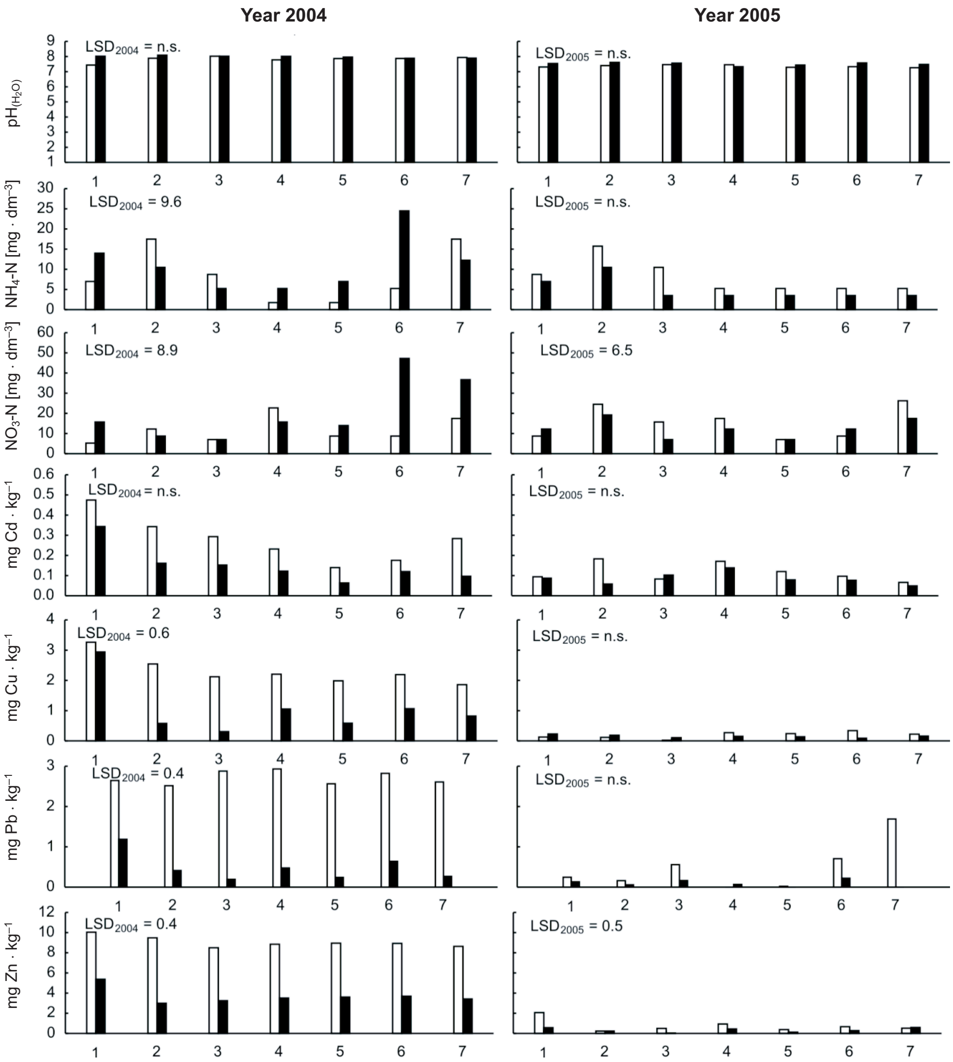

Fig. 1. Effect of nitrogen fertilization on soil reaction (pH) and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb in 0–30 and 30–60 cm soil layers after carrot cultivation in 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. not significant

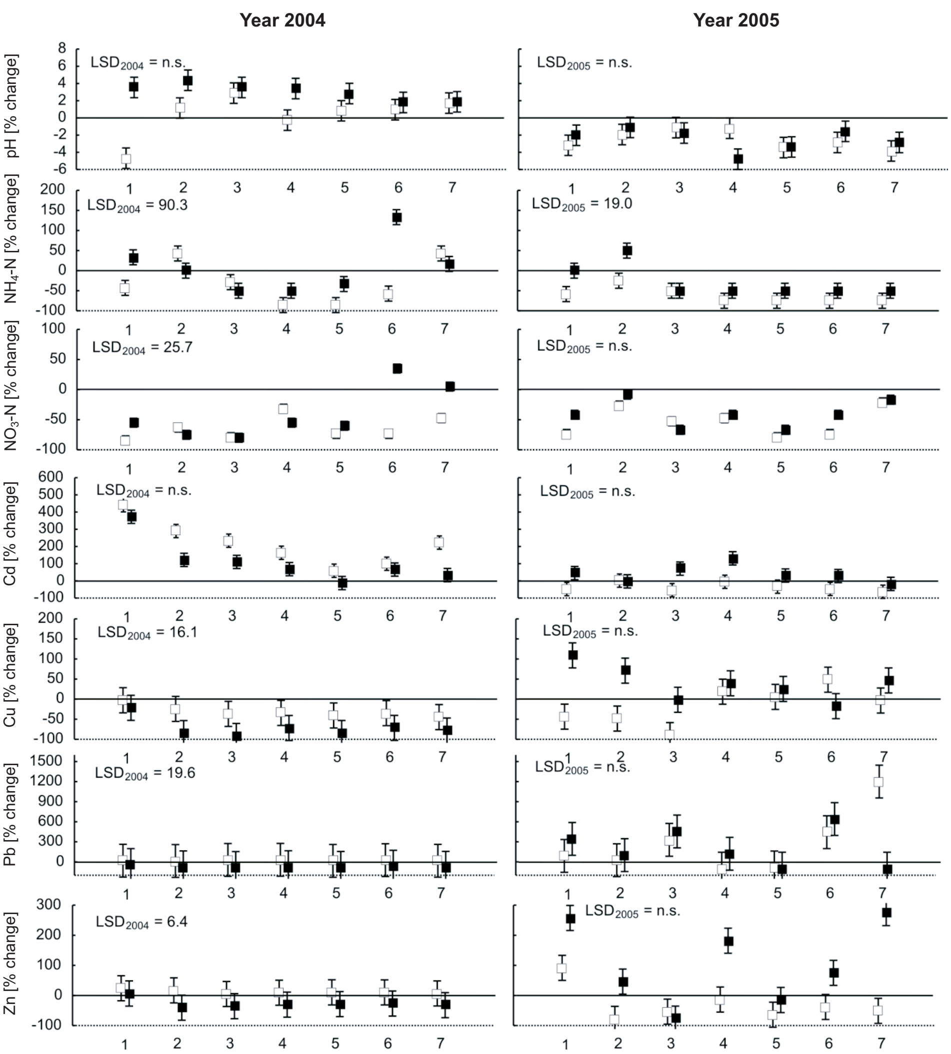

Fig. 2. Effect of nitrogen fertilization on size of changes [%] of chemical characteristics (pH and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb and Zn) in 0–30 and 30–60 cm soil layers after carrot cultivation as compared with the values measured prior to carrot cultivation in 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – ammonium nitrate 35 + 35 kg N, 6 – ammonium nitrate 70 + 70 kg N, 7 – ammonium nitrate 105 + 105 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

105 + 105 kg N · ha^{-1} was characterized by higher content of both forms of nitrogen (NH_4-N and NO_3-N) than the soil fertilized with ENTEC-26 in a similar manner. The relationships mentioned above are difficult to prove on the basis of knowledge about nitrogen transformation in soil environment. These results could have been insignificantly influenced by more effective plant uptake of nitrogen from ENTEC-26

rather than from ammonium nitrate, which has been demonstrated in an earlier work [9]. Study of Gioacchini et al [4] registered a distinct effect of ENTEC-26 on NH_4-N and NO_3-N contents in clay loam and sandy loam. These authors inform that nitrogen availability is, in fact, the end result of interactions between the added substances and the natural soil cycle.

Owing to their chemical characteristics, nitrogen fertilizers can affect soil pH value and, as a result, influence the availability of microelements and heavy metals for plants [6]. In the research by Zaccheo et al [10] 15-day incubation of $(NH_4)_2SO_4$ with DMPP as well as $Ca(NO_3)_2$ did not result in any significant changes in soil reaction as compared with strongly acidifying action of $(NH_4)_2SO_4$ and $(NH_4)_2S_2O_3$. Our research does not reveal any significant influence of doses and time of application of both physiologically acid nitrogen fertilizers on soil pH value or the content of easily soluble forms of Cd, as well as size of change in both these parameters in 0–30 and 30–60 cm layers of the soil after cultivation as compared with initial values (Fig. 1 and 2). In both years of the experiments we observed a differential effect of fertilization with nitrogen on the content of easily soluble forms of Cu, Pb and Zn in 0–30 cm and 30–60 cm layers of soil after cultivation and size of change of these elements in comparison with the values measured in soil before carrot cultivation. There was a significant effect of nitrogen fertilization on the content of Zn in both years of the experiments. Considerable differentiation in the content of Cu and Pb and percentage change in the content of Cu, Pb and Zn in 0–30 cm and 30–60 cm layers of soil in comparison with the initial values was noted in 2004 exclusively. When compared with the control, in both years of the experiments a decrease in the content of Zn as well as Cu in 2004 – was noted in both analyzed layers of soil from all combinations with nitrogen fertilization. Similar relationships were observed in 2004 in case of Pb but only in the layer 30–60 cm. In that year the content of Pb in 0–30 cm layer of soil from all combinations of the experiment was at a comparable level.

Higher amount of rainfall during carrot cultivation in 2005 (Table 2) resulting in an increased quantity of nitrogen leached from the soil (Fig. 1 and 2), caused a significantly shorter interaction of applied fertilizers on soil environment. In that year of the study, the results of Cd, Cu, Pb and Zn content analysis in soil after carrot cultivation indicate that nitrogen fertilizer only insignificantly influenced solubility degree of Cd, Cu, Pb and Zn in both analyzed layers of soil. There is a substantiated hypothesis that mobile fractions of these elements could have been leached to large extent by precipitation waters to soil layers deeper than 60 cm. However, previously published results of the effect of applied nitrogen fertilization on the content of Cd, Cu and Zn storage roots of carrot [7] demonstrated that in 2005 the content of Cd and Cu in carrot was much higher, and the content of Zn insignificantly lower than in 2004. Therefore, the effect of nitrogen fertilizers on the soil content of elements investigated in our research depended not only on their chemical characteristics but also on the physical and chemical properties of soil as well as the course of climatic conditions, with a special emphasis on the amount and distribution of rainfall during cultivation period.

Conclusions

1. In both years of the research, a tendency of higher nitrogen doses applied in the form of ENTEC-26 resulting in the decrease of the content of NH_4-N in 0–30 and 30–60 cm analyzed layers of the soil was observed.
2. Indirectly, a higher effectiveness of nitrification inhibitor DMPP (contained in ENTEC-26) on stabilizing the form NH_4-N in soil environment was noted in 2004, which was characterized by smaller rainfall during carrot cultivation than in 2005.
3. Neither of physiologically acid nitrogen fertilizer applied in the experiments (regardless of nitrogen dose) caused any decrease on soil pH value as well as had no influence on the content of easily soluble forms of Cd, Cu, Pb and Zn in soil.

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WPŁYW NAWOŻENIA ENTEC-26 I SALETRĄ AMONOWĄ NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

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Abstrakt: Badania wykonano w latach 2003–2005. W uprawie marchwi zastosowano: 1 – kontrola (bez nawożenia azotem), 2 – ENTEC-26 35 + 35 kg N, 3 – ENTEC-26 70 + 70 kg N, 4 – ENTEC-26 105 + 105 kg N, 5 – saletrę amonową 35 + 35 kg N, 6 – saletrę amonową 70 + 70 kg N, 7 – saletrę amonową 105 + 105 kg $N \cdot ha^{-1}$; gdzie 35 + 35, 70 + 70 i 105 + 105 oznacza dawkę azotu w $kg N \cdot ha^{-1}$ zastosowaną odpowiednio przedsiewnie i pogłównie.

W przypadku ENTEC-26 [nawóz z inhibitorem nitryfikacji 3,4-dimetylopyrazolofosfatem (DMPP)], w obydwu latach badań wraz ze wzrostem dawki azotu odnotowano tendencję do obniżenia zawartości NH_4-N w obydwu analizowanych warstwach gleby, natomiast nie stwierdzono takich zależności w przypadku nawożenia saletrą amonową. W poszczególnych latach prowadzenia badań wykazano odmienny wpływ nawożenia azotem na zawartość: NH_4-N, NO_3-N, Cd, Cu, Pb i Zn po uprawie oraz na wartości zamian tych parametrów w warstwach 0–30 cm i 30–60 cm gleby w stosunku do wartości zmierzonych przed rozpoczęciem uprawy marchwi. Nie stwierdzono istotnego wpływu zastosowanego nawożenia azotem na odczyn gleby (pH).

Słowa kluczowe: wymywanie azotu, inhibitor nitryfikacji, 3,4-dimetylopyrazolofosfat (DMPP), metale ciężkie