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EFFECT OF NITROGEN FERTILIZERS ON THE CHANGE IN SELECTED CHEMICAL CHARACTERISTICS OF SOIL AFTER CARROT CULTIVATION

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Abstract: In 2003–2005 in carrot cultivation the following combinations were applied (kg N · ha^{-1}): 1 – Control (without N fertilization), 2 – calcium nitrate 70, 3 – calcium nitrate 70 + 70, 4 – ammonium sulphate 70 and 5 – ammonium sulphate 70 + 70; where 70 means 70 kg N · ha^{-1} was used preplant, whereas 70 + 70 that 70 + 70 kg N · ha^{-1} was applied preplant and as a top dressing, respectively.

In the individual years of the research a diversified effect of nitrogen fertilization on the content of NH_4-N, NO_3-N, Cd, Cu, Pb and Zn and soil reaction (pH) after carrot cultivation, as well the size of changes in these chemical characteristics in 0–30 cm and 30–60 cm soil layers were noted when compared with the values measured prior to the start of carrot cultivation. Variable climatic conditions as well as rainfall amount and its distribution significantly influenced the content of mineral nitrogen in 0–30 and 30–60 cm layers of soil after carrot cultivation. In 2003, characterized by the lowest rainfall in the period of carrot cultivation and drought in the summer months, were noted the highest content of NH_4-N in 30–60 cm layer of soil fertilized with presowing and topdressing treatment of ammonium sulfate, and NO_3-N in 0–30 cm layer of soil fertilized with presowing and top dressing treatment of calcium nitrate.

Keywords: nitrogen leaching, heavy metals

One of the negative consequences of using chemical nitrogen fertilizers is the process of NO_3-N leaching from soil into groundwater [1]. Nitrogen losses are greater especially in case of applying fertilizer containing oxidized form of nitrogen (NO_3-N) when compared with those containing reduced form of N (NH_4-N and NH_2-N – present in physiologically acid fertilizers, eg urea and ammonium sulfate) [2]. Nevertheless, application of physiologically acid fertilizer can lead to lowering soil pH value, and consequently cause rise in the content of easily available forms of heavy

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metals in soil. This, in turn, can result in an increase in the content of those elements in yield [3].

This research aimed at determining the effect of calcium nitrate (physiologically alkaline fertilizer) and ammonium sulfate application diversified with regards to dose and time on the change in selected properties of soil after carrot cultivation.

Material and methods

The field experiment on carrot, 'Kazan F_1' cv., cultivation was conducted in 2003–2005 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 28th April 2003, 24th April 2004 and 30th April 2005. The experiments were arranged in a split-plot design in four replications. Experiment comprised of the following treatments (kg N · ha^{-1}): 1 – control (without N fertilization), 2 – calcium nitrate 70, 3 – calcium nitrate 70 + 70, 4 – ammonium sulphate 70 and 5 – ammonium sulphate 70 + 70; where 70 means 70 kg N · ha^{-1} was used preplant, whereas 70 + 70 that 70 + 70 kg N · ha^{-1} was applied preplant and as a top dressing, respectively. Presowing nitrogen fertilization was conducted immediately before bed formation, whereas top dressing was performed at canopy closure (16th June 2003, 1st July 2004 and 30th June 2005).

Table 1

Physical and chemical characteristics of soil layers 0–30 and 30–60 cm prior to the start of experiment in 2003–2005

Characteristics	2003		2004		2005	
	0–30 cm	30–60 cm	0–30 cm	30–60 cm	0–30 cm	30–60 cm
Soli texture class	Clay loam	Clay	Silty clay	Silty clay	Silty clay	Silty clay
Organic matter [%]	3.92	2.52	2.20	1.33	2.26	1.50
pH_{H2O}	7.03	7.52	7.80	7.75	7.55	7.70
NH_4-N [mg · dm^{-3}]	8.8	7.0	12.3	10.5	21.0	7.0
NO_3-N [mg · dm^{-3}]	15.8	15.8	33.3	35.0	33.3	21.0
Cd [mg · kg^{-1}]	0.28	0.06	0.09	0.07	0.18	0.06
Cu [mg · kg^{-1}]	4.38	3.60	3.35	3.75	0.23	0.11
Pb [mg · kg^{-1}]	3.08	1.97	2.22	2.23	0.13	0.03
Zn [mg · kg^{-1}]	11.03	6.92	8.11	5.05	1.08	0.16

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 (15th September 2003, 24th September 2004 and 8th September 2005). At carrot harvesting, average mixed sample was collected from four sites of every combination. Methods of soil analysis included assessment of: soil texture using Casagrande method modified by Pruszynski,

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 2003			Year 2004			Year 2005		
	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]	Average air temperature [°C]	Rainfall [mm]	Sunshine [h]
April	7.4	51.0	233.1	8.7	72.5	237.1	9.1	48.4	189.9
May	16.5	93.6	279.3	12.3	40.9	242.1	13.9	105.1	264.5
June	18.0	75.4	324.8	16.5	64.3	254.4	16.8	109.6	296.6
July	19.5	62.8	269.3	18.5	179.6	272.5	19.8	109.1	291.5
August	19.7	17.3	320.8	18.4	98.8	256.0	17.5	123.9	224.2
September	13.8	43.2	235.5	13.3	22.5	210.9	14.8	62.4	242.0
Mean for growth period	15.8	57.2	277.1	14.6	79.8	245.5	15.3	93.1	251.5
Sum for growth period	—	400.5	1939.9	—	558.4	1718.5	—	651.6	1760.2
Mean for year of study*	8.3	521.0	2226.0	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.

organic matter content with Tiurin method modified by Oleksynowa and pH in H_2O 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.

The 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 (eg chemical characterization of soil in each year of the study) together with the results concerning the effect of fertilization on the quantity and quality of carrot yield have been presented in earlier works [4, 5].

Results and discussion

The lower rainfall during carrot cultivation in 2003, when compared with the years 2004–2005 (Table 2) could have been the reason for a decrease in leached NO_3-N from both analyzed soil samples (Fig. 1 and 2) originating from applied fertilization as well as soil mineralization of organic matter. This is corroborated by the research of other authors [6, 7]. In that year, in 0–30 cm layer of soil fertilized with calcium nitrate dosed as 70 + 70 kg N · ha^{-1} the highest content of NO_3-N was noted in comparison with other combinations. Similarly, this combination revealed the highest growth in content of NO_3-N in the mentioned layer of soil in relation to its content prior to carrot cultivation. In the other two years (2004–2005), considerably higher amount of rainfall during cultivation could have caused intensified nitrogen leaching to soil layers deeper than 60 cm. In these years, both examined soil layers did not differ significantly in the content of NO_3-N with regards to nitrogen dose. Moreover, size of changes in the NO_3-N content in soil after carrot cultivation in relation to its initial content was of negative value, which was not noted in 2003. Research by Westerveld et al [8] revealed that during harvesting carrot cultivated both on mineral and organic soil, the highest content of NO_3-N (in all sites fertilized with nitrogen) was present in 0–30 cm soil layer rather than in deeper layers, 30–60 and 60–90 cm. These authors analyzed the content of NO_3-N and NH_4-N in individual layers of soil only in the last year of their three-year research cycle and carrot was grown for three years on the same field.

Information presented by Gorlach and Mazur [2] indicated that ions NH_4^+, as opposed to NO_3^-, after their introduction into soil with fertilizers containing NH_4-N, are absorbed by sorption complex to larger degree than leached to the deeper layers of soil. In our study, despite the lack of statistical differences between the combinations in the content of NH_4-N in soil (Fig. 1 and 2) it should be emphasized that in 2003 after carrot cultivation in 30–60 cm layer of soil fertilized with ammonium sulfate dosed as 70 + 70 kg N · ha^{-1}, the highest content of this form of nitrogen as well as statistically highest increase in percentage content of NH_4-N were observed when compared with its content

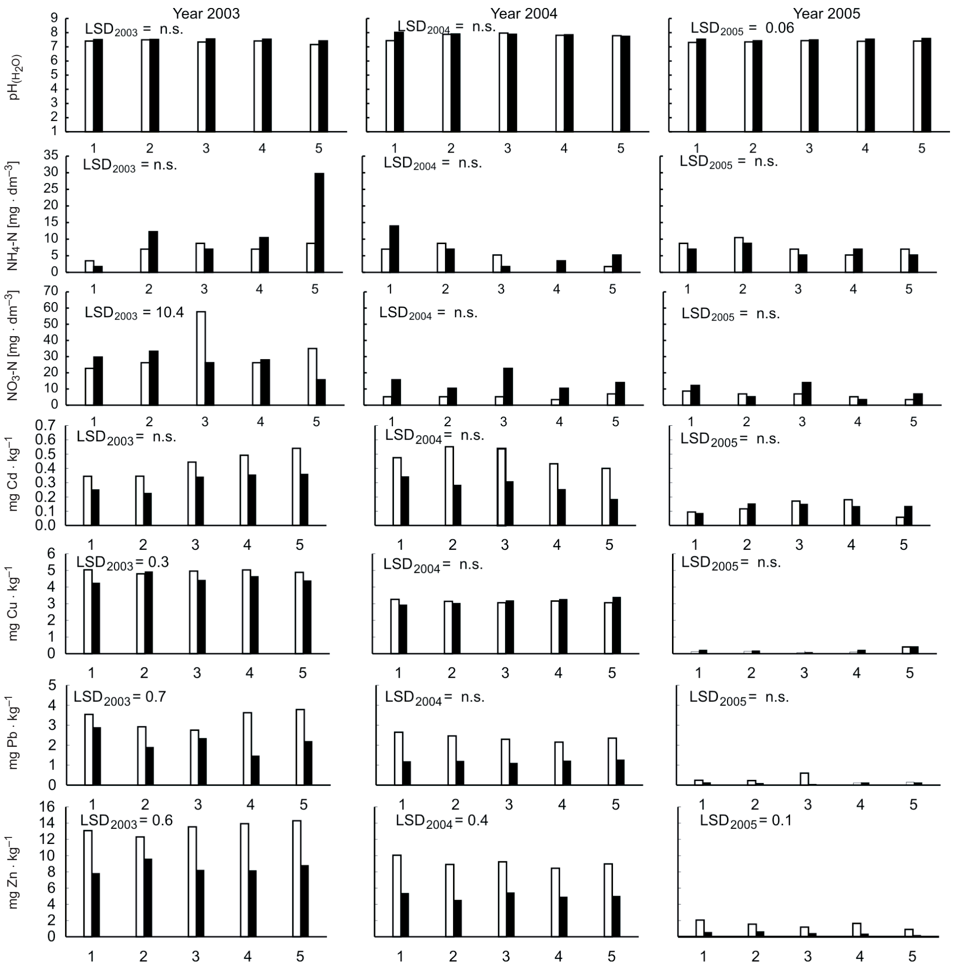

Fig. 1. Effect of nitrogen fertilization on soil reaction (pH) and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb in 0–30 and 30–60 cm soil layers after carrot cultivation in 2003, 2004 and 2005
Explanation: □ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – calcium nitrate 70 kg N, 3 – calcium nitrate 70 + 70 kg N, 4 – ammonium sulphate 70 kg N and 5 – ammonium sulphate 70 + 70 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

in soil prior to carrot cultivation. It is difficult to interpret such a interrelation. Study by Sweeney and Granade [9] showed that fertilization with $(NH_4)_2SO_4$ increased the levels of extractable SO_4^{2-} in the soil, especially in layers deeper than 15 cm. It is possible that in our study SO_4^{2-} ions contained in ammonium sulfate were leached to 30–60 cm soil layer, especially after applied top dressing treatment. During the period of drought in the summer months that process could have been inhibited. Under the conditions of elevated concentration of SO_4^{2-} in 30–60 cm soil layer, these ions could have been fixing with NH_4^+ ions created in the process of soil mineralization of organic matter. The drought (in July, August and the beginning of September 2003) combined with

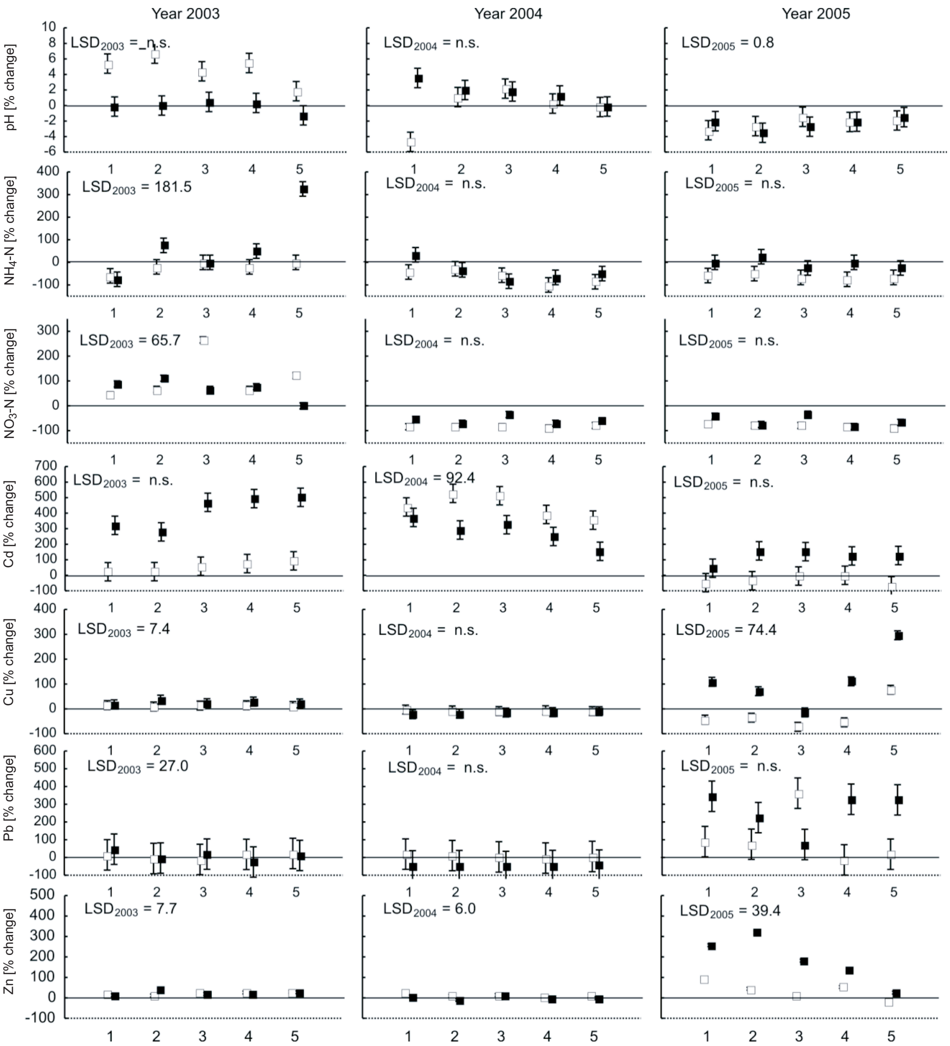

Fig. 2. Effect of nitrogen fertilization on size of changes [%] of chemical characteristics (pH and the content of: NH_4-N, NO_3-N, Cd, Cu, Pb and Zn) in 0–30 and 30–60 cm soil layers after carrot cultivation as compared with the values measured prior to the start of carrot cultivation in 2003, 2004 and 2005
Explanation: ☐ layer 0–30 cm, ■ layer 30–60 cm, 1 – control (without N fertilization), 2 – calcium nitrate 70 kg N, 3 – calcium nitrate 70 + 70 kg N, 4 – ammonium sulphate 70 kg N and 5 – ammonium sulphate 70 + 70 kg N · ha^{-1}; LSD = fertilization × soil layers; n.s. – not significant

elevated temperature of soil could have additionally contributed to stabilizing NH_4^+ in soil environment due to weakened process of nitrification [2].

In individual years of the experiment was noted a significant effect of applied nitrogen fertilization particularly on the content of Zn in both analyzed layers of soil (Fig. 1 and 2). However, the influence of nitrogen fertilization on the soil pH and the content of Cd, Cu and Pb in individual layers of soil was relatively insignificant. In

2003 the highest content of Zn in 0–30 cm soil layer was noted after presowing and top dressing treatment with ammonium sulfate, and after presowing treatment in 30–60 cm layer in case of soil fertilized with calcium nitrate. In 2004–2005 the highest level of Zn in 0–30 cm layer was revealed in the soil from control site, and in case of 30–60 cm layer of the soil fertilized with calcium nitrate after presowing and top dressing in 2004 and only presowing in 2005. It should be emphasized that after carrot cultivation in 2005, in comparison with 2003–2004, we noted a relatively high increase in percentage content of Pb and Zn forms soluble in 0.01 mol $\cdot$ dm^{-3} $CaCl_2$ both in 0–30 cm and 30–60 cm and Cu in 30–60 cm soil layer. We did not note these dependencies in case of Cd. It is further worth noting that despite a dissimilar influence of nitrogen fertilization on the content of Cd, Cu, Pb and Zn as well as soil pH after cultivation (and size of changes of these parameters in relation to the values measured prior to the cultivation) we did not found any significant effect of research factors on the content of these elements in carrot storage roots in all years of the experiments [4].

Conclusions

1. Variable climatic conditions, and rainfall amount and its distribution, significantly influenced the content of mineral nitrogen in 0–30 and 30–60 cm layers of soil after carrot cultivation.

2. In 2003, characterized by the lowest rainfall in the period of carrot cultivation and drought in the summer months, we noted the highest content of NH_4-N in 30–60 cm layer of soil fertilized with presowing and topdressing treatment of ammonium sulfate, and NO_3-N in 0–30 cm layer of soil fertilized with presowing and top dressing treatment of calcium nitrate.

3. Diversified effect of nitrogen fertilization on soil pH value and the content of Cd, Cu, Pb and Zn in 0–30 and 30–60 cm soil layers after carrot cultivation was revealed in individual years of the research.

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WPŁYW STOSOWANIA NAWOZÓW AZOTOWYCH NA ZMIANY WYBRANYCH CHEMICZNYCH WŁAŚCIWOŚCI GLEBY PO UPRAWIE MARCHWI

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Abstrakt: Badana wykonano w latach 2003–2005. W uprawie marchwi zastosowano (kg N · ha^{-1}): 1 – kontrola (bez nawożenia azotem), 2 – saletra wapniowa 70, 3 – saletra wapniowa 70 + 70, 4 – siarczan amonu 70, 5 – siarczan amonu 70 + 70; gdzie 70 oznacza 70 kg N · ha^{-1} zastosowane przedsiewnie, podczas gdy 70 + 70 odpowiednio 70 + 70 kg N · ha^{-1} azot zastosowany przedsiewnie i pogłównie.

W poszczególnych latach prowadzenia badań wykazano odmienny wpływ nawożenia azotem na zawartość: N-NH_4, N-NO_3, Cd, Cu, Pb i Zn, jak i na odczyn gleby (pH) po uprawie oraz na zakres zmian tych właściwości w warstwach 0–30 i 30–60 cm gleby w stosunku do wartości zmierzonych przed rozpoczęciem uprawy marchwi. Zróżnicowane warunki klimatyczne, ilość i rozkład opadów, miały znaczny wpływ na zawartość azotu mineralnego w 0–30 i 30–60 cm warstwach gleby po uprawie marchwi. W roku 2003 charakteryzującym się najmniejszą ilością opadów w okresie uprawy marchwi oraz suszą w miesiącach letnich stwierdzono największą zawartość N-NH_4 w 30–60 cm warstwie gleby nawożonej przedsiewnie i pogłównie siarczanem amonu, a N-NO_3 w 0–30 cm warstwie gleby nawożonej przedsiewnie i pogłównie saletrą wapniową.

Słowa kluczowe: wymywanie azotu, metale ciężkie