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THE EFFECT OF NITROGEN FERTILIZATION ON RADISH YIELDING

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Abstract. In two field experiments carried out in 2006–2008, with two radish cultivars Treto F_1 and Wernar F_1 the effect of differentiated nitrogen fertilization on yield and biological value of radish grown for autumn harvest was examined. Mineral N content in the soil before seeds sowing was raised up to the level of: 50, 100 and 150 mg $N \cdot dm^{-3}$ by using: ammonium nitrate 34% N – $[NH_4NO_3]$, calcium nitrate 15.5% N – $[Ca(NO_3)_2 \cdot H_2O]$, ammonium sulphate 20.0% N – $[(NH4)_2SO_4]$, and ENTEC 26% N – $[NH_4NO_3+(NH_4)_2SO_4$ + 0.8% DNPP]. The highest marketable yield of radish Treto F_1 cv. was achieved in the case of ammonium nitrate use. In the case of Wernar F_1 cv. kind of fertilizer didn't affect the yield. Irrespective of the kind of fertilizer, increment of nitrogen content in the soil from 50 to 100 mg $N \cdot dm^{-3}$ caused the significant enhancement of radish yield. The similar yielding was recorded at nitrogen concentration equal to 150 mg $N \cdot dm^{-3}$ and 100 mg $N \cdot dm^{-3}$. Increasing mineral nitrogen concentration in the soil resulted in increment of nitrates content in radish roots, however their amounts not exceed permissible level. Plants fertilized with ammonium sulphate and ENTEC 26 contained lower amount of nitrates in edible parts in comparison to those supplied with ammonium nitrate and calcium nitrate.

Key words: radish, nitrogen dose, nitrogen form, yield, crop quality

INTRODUCTION

Radish is a vegetable characterizing short growing period, cultivated both in the field and under the covers. According to Stępowska and Rogowska [2006], radish cultivation area in Poland amounts about 700 ha, out of which one third belongs to field cultivation. Featuring short plant growing period and underdeveloped root system, radish requires high quantity of easily available nutrients in soil and , although its nutrient uptake is relatively low, fertilization needs are classified as high ones. Skąpski and

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Dąbrowska [1994] reported that to produce the yield ranging 10 t·ha^{-1} radish requires approximately 50 kg N, 20 kg P_2O_5, 50 kg K_2O and 30 kg CaO.

Among the factors deciding about successful cultivation of this vegetable, nitrogen fertilization is of a special meaning and application level of this element should be targeted not only on the yield size, but, first of all, yield quality [Kowalska et al. 2006, Wojciechowska and Siwek 2006]. Radish belongs to a group of vegetables characterizing a high tendency to nitrates accumulation, which can result in its decreased usefulness [Rożek 2000]. This disadvantageous phenomenon can be reduced through rational fertilization with nitrogen, adjusted to radish nutrition needs, as well as to nitrogen content in the soil. However, recommended optimum nitrogen concentration proves to be highly diversified: Stępowska and Rogowska [2006] state that optimum nitrogen content for heavy soil should amount 120–150 mg N·dm^{-3}, while for light soils it should range 80–100 mg N·dm^{-3}, while Breś et al. [2008] suggest even wider range of nitrogen – richness, namely 50–130 mg N·dm^{-3}. Considerably lower amounts are recommended by Orłowski and Kołota [1999], found within the range 40–50 kg N·ha^{-1}. When cultivating radish, a special attentin should be paid not only to nitrogen dose, but to the form of nitrogen fertilizer as well [Kowalska et al. 2006]. If ammonium form is applied (ammonium sulfate) or amide form (urea), nitrates content in radish roots is usually lower than that of nitrate form introduced [Michałojć 2001]. The aim of research was the assessment of the effect of nitrogen dose and form on yielding and nitrates accumulation in roots of two radish cultivars.

MATERIALS AND METHODS

Field experiment regarding radish cultivation was conducted in the years 2006–2008. It was established as two – factorial experiment according to the spilt – plot method, in three replications. The first factor (A) were diversified nitrogen amounts in soil before radish cultivation, ranging: 50, 100 and 150 mg N·dm^{-3}. The second factor (B) involved 4 nitrogen fertilizers differing in chemical composition and nitrogen form introduced into soil: ammonium nitrate 34% N – [NH_4NO_3], calcium nitrate 15.5% N – [$Ca(NO_3)_2 \cdot H_2O+NH_4NO_3$], ammonium sulfate 20.0% N – [$(NH4)_2SO_4$] and ENTEC 26% N – [$NH_4NO_3+(NH_4)_2SO_4$ + 0.8% DNPP]. ENTEC 26 fertilizer includes nitrification inhibitor 3.4 dimetylopyrasophosphate, which purpose is to stabilize ammonium form of nitrogen through blocking the activity of *Nitrosomonas* species bacterias. Mineral nitrogen concentration in control without nitrogen fertilization amounted from 30 to 40 mg ($N\text{-}NO_3$ + $N\text{-}NH_4 \cdot dm^{-3}$) and the remaining components maintained the level meeting radish nutritional requirements, pH 7.0–7.4 and organic matter 1.8%. In two independent experiments there were cultivated two radish cultivars: Treto F_1 featuring elongated roots and Wernar F_1 ,of spherical roots. Radish seeds were sown in IIIrd decade of August on plots measuring 1.0 × 1.2 m, in the amount of 3.5 g·m^{-2}. Spacing between rows equaled 15 cm. After germination the seedlings were thinned to keep the distance of 2.5 cm. between the plants in the rows. Radish was harvested at the end of September and in early October, according to roots reaching a diameter of 2.0 cm. Qualitative analysis of radish yield consisted in determination of nitrates content according to potentiometric method, with the use of Orion electrode, and dry matter content (after drying at 105°C to constant weight) in radish roots. The results were subjected to statistical analysis and the least significant differences calculated by Tukey's test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Regardless the form of nitrogen fertilizer introduced, enhancement the content of this element in the soil from 50 to 100 mg $N \cdot dm^{-3}$ caused significantly increase of marketable yield of radish in both cultivars subjected to examination. Further enhancement of nitrogen concentration, up to 150 mg $N \cdot dm^{-3}$ contributed to the increase in average yield, although differences between nitrogen fertilization doses 100 and 150 $N \cdot dm^{-3}$ were not statistically confirmed. The results obtained in the study confirm the positive effect of N on the yield reported by Gorlach and Mazur [2002], as well as the data obtained by Stępowska and Rogowska [2006], indicating that in the heavy soils concentration of this element for radish should be kept at the range of 100 mg $N \cdot dm^{-3}$.

Application of ammonium sulphate as a source of nitrogen in the case of Treto F_1 cultivar allowed to obtain significantly higher yielding in comparison to the remaining fertilizers. The use of ammonium sulphate and ENTEC 26 fertilizer resulted in yield size of comparable levels. Yet plants fertilized with calcium nitrate featured significantly lower yield values (tab. 1). In Wernar F_1 cultivar average marketable yield was not, generally, dependent on the form of nitrogen fertilizer used as average values did not markedly differ. The lowest average marketable yield in this cultivar was obtained when ENTEC 26 fertilizer was introduced as a source of nitrogen.

The results recorded for our own investigation did not fully confirm information reported by Hähndel and Zerulla [2001], who proved especially advantageous effect of ENTEC 26 application on radish yielding. In the latter experiments radish yield did increase by 11.1% as compared to other fertilizers. Our own research showed similar yielding data for Treto F_1 cultivar under the influence of fertilization with ammonium sulfate and ENTEC 26. That situation could be caused by different soil conditions, since, according to Kołota and Adamczewska-Sowińska [2007] introduction of ENTEC 26 fertilizer proves advantageous first of all on light soils, when accompanied by high precipitation and intensive watering

The use of ammonium nitrate in the dose of 100 mg $N \cdot dm^{-3}$ allowed to obtain the highest average marketable yield of Treto F_1 cultivar in the whole experiment and very high yield of Wernar F_1 cultivar.

Increasing nitrogen concentration in soil used for radish cultivation caused decreased values of dry matter content in radish roots in comparison to control treatment. Analyzing examined ranges of soil richness in nitrogen it should be stated that the highest average content of dry matter in radish roots characterized plants cultivated at soil amounting 50 mg $N \cdot dm^{-3}$, and only a slightly lower one at 100 mg $N \cdot dm^{-3}$. Further increase in nitrogen concentration to 150 mg $N \cdot dm^{-3}$ resulted in considerable decrease in average content of dry matter in radish. Similar tendencies were found in both radish cultivars (tab. 2).

Table 1. The effect of nitrogen fertilization on marketable yield of radish (mean for 2006–2008 in $t \cdot ha^{-1}$)

Tabela 1. Wpływ nawożenia azotem na plon handlowy zgrubień rzodkiewki (średnio dla lat 2006–2008 w $t \cdot ha^{-1}$)

Cultivar Odmiana	Kind of fertilizer Rodzaj nawozu	Mineral nitrogen content in soil Zawartość azotu mineralnego w glebie $mg\ N \cdot dm^{-3}$			Mean Średnia
		50	100	150	
Treto F_1	ammonium sulphate siarczan amonu	13.47	13.52	14.17	13.72
	ammonium nitrate saletra amonowa	13.41	15.84	14.61	14.62
	calcium nitrate saletra wapniowa	12.22	12.69	12.47	12.46
	ENTEC 26	13.13	13.33	14.90	13.79
	mean – średnia	13.06	13.85	14.04	13.65
	control – kontrola				6.66
$LSD_{0.05}$ for: N dose – 0.54, kind of fertilizer – 0.81, interaction I × II – 1.08 $NIR_{\alpha = 0,05}$ dla: dawki N – 0,54, rodzaju nawozu – 0,81, interakcji I × II – 1,08					
Wernar F_1	ammonium sulphate siarczan amonu	12.22	11.90	12.85	12.32
	ammonium nitrate saletra amonowa	10.72	13.38	13.07	12.39
	calcium nitrate saletra wapniowa	11.53	11.59	13.41	12.18
	ENTEC 26	11.44	12.51	11.40	11.79
	mean – średnia	11.48	12.35	12.68	12.17
	control – kontrola				8.29
$LSD_{0.05}$ for: N dose – 0.49. kind of fertilizer – 0.52. interaction – 0.94 $NIR_{\alpha = 0,05}$ dla: dawki N – 0,49, rodzaju nawozu – 0,52, interakcji – 0,94					

Also the form of nitrogen fertilizer did affect on dry matter accumulation in roots. In both examined cultivars the highest content of dry matter featured radish roots fertilized with ammonium nitrate. In the case of Treto F_1 cultivar the use of calcium nitrate brought about significant decrease in dry matter content in radish roots as compared to the remaining fertilizers. In Wernar F_1 cultivar there was observed a similar tendency, although differences were not confirmed statistically. Apart from the yield size, yield quality is of the same importance. As far as radish is concerned, it is very important to maintain a proper nitrates level which should not exceed 1500 mg $NO_3 \cdot kg^{-1}$ of fresh matter.

According to Kozik and Gleń [1995], nitrates content in plants is strictly related to the dose and form of nitrogen applied, which can be confirmed by the results of this study. The smallest amounts of those compounds were found in radish roots grown in the control treatment. In Sady's opinion [2006] nitrogen dose is one of the basic factors governing nitrates content in vegetables, which was also proved in our experiments. Increased concentration of mineral nitrogen in soil resulted in significant enhancement of average content of nitrates in radish. In Treto F_1 the increase in nitrogen concentration from 50 mg $N \cdot dm^{-3}$ to 150 mg $N \cdot dm^{-3}$ provided for the increase in average nitrates content from 431.8 mg $NO_3 \cdot kg^{-1}$ to 791.1 mg $NO_3 \cdot kg^{-1}$, while in Wernar F_1 cultivar the values grew from 492.8 mg $NO_3 \cdot kg^{-1}$ to 851.9 mg $NO_3 \cdot kg^{-1}$, respectively (tab. 3). The form of fertilizer used was also of not the least importance as it significantly affected nitrates concentration in radish.

Table 2. The effect of nitrogen fertilization on dry matter content of radish roots (mean for 2006–2008 in %)
Tabela 2. Wpływ nawożenia azotem na zawartość suchej masy w zgrubieniach rzodkiewki (średnio dla lat 2006–2008 w %)

Cultivar Odmiana	Kind of fertilizer Rodzaj nawozu	Mineral nitrogen content in soil Zawartość azotu mineralnego w glebie mg $N \cdot dm^{-3}$			Mean Średnia
		50	100	150	
Treto F_1	ammonium sulphate siarczan amonu	4.94	4.80	4.30	4.68
	ammonium nitrate saletra amonowa	5.29	5.26	4.33	4.96
	calcium nitrate saletra wapniowa	4.46	4.06	3.99	4.17
	ENTEC 26	4.95	4.91	4.21	4.69
	mean – średnia	4.91	4.76	4.21	4.63
	control – kontrola				5.24
$LSD_{0.05}$ for: N dose – 0.24, kind of fertilizer – 0.32, interaction – 0.41 $NIR_{\alpha = 0,05}$ dla: dawki N – 0,24, rodzaju nawozu – 0,32, interakcji – 0,41					
Wernar F_1	ammonium sulphate siarczan amonu	4.72	4.51	3.92	4.38
	ammonium nitrate saletra amonowa	4.76	4.42	4.70	4.63
	calcium nitrate saletra wapniowa	4.24	4.72	4.09	4.35
	ENTEC 26	5.14	4.28	4.09	4.51
	mean – średnia	4.72	4.49	4.20	4.47
	control – kontrola				5.19
$LSD_{0.05}$ for: N dose – 0.26, kind of fertilizer – n.s., interaction – 0.38 $NIR_{\alpha = 0,05}$ dla: dawki N – 0,26, rodzaju nawozu – r.n., interakcji – 0,38					

Application of ammonium sulfate and ENTEC 26 fertilizer in the case of Treto F_1 cultivar did markedly contribute to diminished accumulation of nitrates in radish roots as compared to the remaining fertilizers. The results mentioned above remain in agreement with the data reported in the literature which point to the fact that fertilization with reduced forms of nitrogen did significantly contribute to the decrease in nitrates content in horticultural products [Wojciechowska 2004, Michałojć 2001, Barczak and Cwojdziński 1996, Lisiewska 1991, Jurkowska and Rożek 1981].

As far as Wernar F_1 cultivar was taken into account, the best effects of reducing nitrates accumulation were obtained as a result of ENTEC 26 fertilizer application since the fertilizer in question does contain nitrogen in ammonium and nitrate form. That fertilizer brought about lower accumulation of nitrates by 23.1% in Treto F_1 cultivar and by 41.6% in Wernar F_1 cultivar in comparison to ammonium nitrate. Similar results were reported by Kołota and Adamczewska-Sowińska [2007] in red beet and celery cultivation. The use of ammonium and calcium nitrates resulted in considerable increase in average nitrates content in two radish cultivars as compared to the remaining fertilizers subjected to examination. Nitrates content was definitely higher after application of calcium nitrate, which is consistent with results reported by Michałojć [2001], who recorded increased nitrates content in edible parts of lettuce, radish and spinach fertilized with calcium nitrate in comparison to the values obtained for fertilization with ammonium nitrate. It should be stressed, however, that none of nitrogen doses used or the forms of fertilizers applied did provide for exceeding permissible dose of nitrates in radish roots.

Table 3. The effect of nitrogen fertilization on nitrate content of radish roots (mean for 2006–2008 in mg $NO_3 \cdot kg^{-1}$ f.m.)
Tabela 3. Wpływ nawożenia azotem na zawartość azotanów w zgrubieniach rzodkiewki (średnio dla lat 2006–2008 w mg $NO_3 \cdot kg^{-1}$ św.m.)

Cultivar Odmiana	Kind of fertilizer Rodzaj nawozu	Mineral nitrogen content in soil Zawartość azotu mineralnego w glebie mg $N \cdot dm^{-3}$			Mean Średnia
		50	100	150	
Treto F_1	ammonium sulphate siarczan amonu	252.6	493.8	641.7	462.7
	ammonium nitrate saletra amonowa	479.7	639.9	743.0	620.9
	calcium nitrate saletra wapniowa	661.3	1012.4	1167.8	947.1
	ENTEC 26	333.8	488.3	611.9	478.0
	mean – średnia	431.8	658.6	791.1	627.2
	control – kontrola				211.5
$LSD_{0.05}$ for: N dose – 48.1, kind of fertilizer – 65.4, interaction – 74.5 $NIR_{\alpha = 0,05}$ dla: dawki N – 48,1, rodzaju nawozu – 65,4, interakcji – 75,4					
Wernar F_1	ammonium sulphate siarczan amonu	385.1	537.3	518.8	480.4
	ammonium nitrate saletra amonowa	499.9	588.3	1030.8	706.3
	calcium nitrate saletra wapniowa	799.4	953.8	1116.2	956.5
	ENTEC 26	286.8	353.9	597.7	412.8
	mean – średnia	492.8	608.3	815.9	639.0
	control – kontrola				253.7
$LSD_{0.05}$ for: N dose – 42.2, kind of fertilizer – 51.2, interaction – 68.2 $NIR_{\alpha = 0,05}$ dla: dawki N – 42,2, rodzaju nawozu – 51,2, interakcji – 68,2					

Taking into account the quality and yield size it is possible to state that the best results regarding radish production were obtained for radish cultivated at soil content ranging 100 mg $N \cdot dm^{-3}$ when ammonium sulfate and ENTEC 26 fertilizer were used as a source of nitrogen.

CONCLUSIONS

1. The most advantageous source of nitrogen for Treto F_1 cultivar of radish was ammonium nitrate which, in comparison to ammonium sulfate, calcium nitrate and ENTEC 26 fertilizer allowed to obtain the highest marketable yield of radish. In the case of Wernar F_1 cultivar the effect of the form of nitrogen fertilizer on marketable yield was, generally, not significant.

2. Regardless the form of nitrogen fertilizer applied, the increase in concentration of this element in soil from 50 to 100 mg $N{\cdot}dm^{-3}$ did considerably contribute to the increase in radish marketable yield. At nitrogen content ranging 150 mg $N{\cdot}dm^{-3}$ radish yield maintained a similar level to that obtained at 100 mg $N{\cdot}dm^{-3}$.

3. Application of high nitrogen doses resulted in the decrease of dry matter content in radish roots

4. Radish fertilized with ammonium sulfate and ENTEC 26 fertilizer featured significantly lower average content of nitrates in the roots.

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WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE RZODKIEWKI

Streszczenie. Rzodkiewka jest warzywem o krótkim okresie wegetacji, uprawianym zarówno w polu, jak i pod osłonami. Krótki okres wegetacji i słabo rozwinięty system korzeniowy rzodkiewki sprawia, że wymaga ona dużej ilości łatwo dostępnych składników pokarmowych w glebie i mimo że jest rośliną o małych wymaganiach pokarmowych, jej potrzeby nawozowe są klasyfikowane jako duże. Szczególną uwagę należy zwrócić na nawożenie azotem z powodu jego wpływu na jakość i ilość plonu. W latach 2006–2008 przeprowadzono doświadczenia polowe z dwoma odmianami rzodkiewki – Treto F_1 i Wernar F_1, uprawianymi na zbiór jesienny. Oceniano wpływ zróżnicowanych dawek azotu zapewniających uzyskanie zasobności gleby przed siewem nasion, na poziomie: 50, 100 i 150 mg $N \cdot dm^{-3}$ oraz 4 nawozy różniące się formą azotu: saletra amonowa 34% N – [NH_4NO_3], saletra wapniowa 15,5% N – [$Ca(NO_3)_2 \cdot H_2O$], siarczan amonu 20,0% N – [$(NH_4)_2SO_4$], ENTEC 26% N – [NH_4NO_3+$(NH_4)_2SO_4$ + 0,8% DNPP. Najwyższy plon handlowy rzodkiewki odmiany Treto F_1 zapewniło użycie saletry amonowej, która w porównaniu z saletrą wapniową, siarczanem amonu i nawozem ENTEC 26 zapewniła uzyskanie najwyższych plonów zgrubień. W przypadku odmiany Wernar F_1 wpływ rodzaju nawozu azotowego na plon handlowy był z reguły nieistotny. Niezależnie od rodzaju zastosowanego nawozu azotowego zwiększenie koncentracji tego składnika w glebie z 50 do 100 mg $N \cdot dm^{-3}$ powodowało istotny wzrostu plonu handlowego rzodkiewki. Przy zawartości 150 mg $N \cdot dm^{-3}$ plon ten utrzymywał się na podobnym poziomie jak przy 100 mg $N \cdot dm^{-3}$. Zawartość azotanów w zgrubieniach rzodkiewki wzrastała wraz ze zwiększaniem koncentracji azotu w glebie, ale nie przekraczała dopuszczalnych norm. Rośliny nawożone siarczanem amonu i nawozem ENTEC 26 zawierały istotnie mniejsze ilości azotanów w częściach jadalnych w porównaniu z nawożonymi saletrą amonową i saletrą wapniową.

Słowa kluczowe: rzodkiewka, dawka i forma azotu, plonowanie, jakość plonu

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