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EFFECT OF NITROGEN FORM AND DOSE ON NITRATES(V) CONTENT IN SELECTED SPECIES OF VEGETABLES

WPŁYW DAWKI I FORMY AZOTU NA ZAWARTOŚĆ AZOTANÓW(V) W WYBRANYCH GATUNKACH WARZYW

Abstract: The aim of this work was the assessment of the effect of increasing doses of different forms of nitrogen nitrates(V) accumulation in lettuce and radish roots. Research was carried out on the basis of exact cultivation experiments conducted in the years 2003–2005 in a cold greenhouse. The two plant species were fertilized in each year of the experiment, in spring and autumn, with following doses of nitrogen 0.5; 1.0; 1.5; 2.0; and 3.0 g N · pot^{-1} , introducing nitrogen in the forms of $(NH_4)_2SO_4$, $Ca(NO_3)_2$, NH_4NO_3 and $CO(NH_2)$. Investigation was conducted on light soil of slightly acid reaction, featuring the following contents of chemical elements: low-potassium, medium-phosphorus and high-magnesium. The effect of nitrogen form and dose was assessed through analysis of yield size of cultivated plants, total nitrogen and nitrates(V) content. After investigation had been finished, there was determined the content of mineral nitrogen in soils. The research proved that both lettuce and radish yields increased according to gradually increasing dose of nitrogen, up to 1.5 g N · pot^{-1}. The most intensive yield–forming effect in the case of lettuce showed calcium saltpetre, while for radish it was ammonium saltpetre. Significantly higher yields of both plants originating from the same treatments were obtained from spring cultivation. The highest concentration of nitrate(V) nitrogen was assayed in both plants when fertilization with the highest nitrogen dose, yet it was always lettuce to contain higher amounts of this element than radish. Lower quantities of nitrates(V) in each of the examined species were recorded in the spring, while in the autumn these values were higher. Regardless the species, the highest amount of nitrates(V) were accumulated in plants fertilized with calcium and ammonium saltpetre, while the lowest quantities were obtained for application of ammonium sulfate.

Keywords: nitrogen fertilization, forms of nitrogen, nitrate(V) nitrogen, term of cultivation, lettuce, radish

Among a number of cultivation technology factors nitrogen fertilization features the most profound effect on nitrates(V) accumulation in plants. It was reported [1, 2], that under the influence of increasing fertilization with selected forms of nitrogen there occurs increased uptake of this element by plants, but nitrogen usability for protein

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synthesis becomes gradually less efficient. As a result a considerable increase in nitrate(V) fraction contribution to total nitrogen becomes a fact. Apart from the dose of nitrogen fertilizer, the very form of nitrogen, contained in the fertilizer in question, significantly effects on nitrates(V) accumulation. It was proved that the most considerable effect on accumulation of this nitrogen form in plant tissues characterizes fertilization with saltpetre form of nitrogen. The latter one is of a quick effect and nitrate(V) ion, not stored in soil, is quickly absorbed by plants. When nitrogen is applied in the form of ammonium, nitrogen uptake is markedly lower as it depends on nitrification process, as well as the pace of releasing nitrate(V) ions to soil solution [3–5]. Numerous authors also agree that the length of plant growing period and light conditions do considerably effect on nitrates(V) concentration in plants. The highest concentrations are detected in early stages of plant development, and generally, as the plant growing period went by, nitrates(V) content decreases [6–9]. An important role in nitrates(V) accumulation is also played by the term of cultivation and nitrates(V) content, is the highest in winter and early spring, while the lowest values were recorded in late autumn and in the summer, which is connected with intensity of daylight and photosynthesis and results in nitrates(V) reduction [10–12].

Material and methods

Research was conducted on the basis of exact cultivation – pot experiment carried out in years 2003–2005. Investigation was conducted on a light soil of slightly acid reaction, featuring the following contents of chemical elements: low-potassium, medium-phosphorus and high-magnesium. In order to provide proper conditions for plants grow and development basic mineral fertilization for pot experiments was applied. Seeds of lettuce and radish were sow in prepared soil and each experimental object was cultivated in 4 replications. After germination in every pot 8 plants were left. Nitrogen was applied as $(NH_4)_2SO_4$, $Ca(NO_3)_2$, NH_4NO_3 and $CO(NH_2)$ in increasing doses 0.5; 1.0; 1.5; 2.0; and 3.0 g N $\cdot$ pot^{-1}. All the nitrogen doses were divided – one half was applied before sawing and the second half in two doses was applied during vegetation. The two plant species were cultivated in each year of the experiment, in the spring and in the autumn. During the vegetation period soil humidity and plant health were controlled. Ripe plants were collected and mass of yield as well as content of nitrogen(V) by xylenol method were determined. After completing the investigation soil samples from pots were collected and total nitrogen content by Kiejdahl method, as well as nitrate(V) and ammonium nitrogen were determined. Both forms were measured by colorimeters – nitrate(V) nitrogen with diphenylosulfone acid and ammonium nitrogen with Nessler's reagent.

Results and discussion

Nitrogen fertilization contributed to a significant increase in yield size of lettuce and radish, as compared with control treatment, when this component was applied up to the dose of 1.5 g N per pot Table 1. At higher doses in each case there was observed

evident, significant yield size reduction of both plants, which speaks for the fact that in order to obtain maximum yielding, according to a typical course of a yielding curve, it is sufficient to introduce halved doses of nitrogen in relation to the ones used in the experiment. The data in Table 1 evidently point to the fact that yields of lettuce and radish cultivated in the spring were higher than those originating from the autumn.

Table 1

Lettuce and radish yield

Form of nitrogen	Nitrogen dose [g N · pot^{-1}]	Spring harvest		Autumn harvest	
		Lettuce	Radish	Lettuce	Radish
		[g d.m. · pot^{-1}]			
	0.0	10.1	6.8	1.0	2.3
$(NH_4)_2SO_4$	0.5	12.8	7.4	2.8	3.6
	1.0	14.9	8.9	3.9	4.2
	1.5	19.9	9.9	4.9	5.4
	2.0	7.6	3.4	1.7	1.7
	3.0	4.6	2.8	1.0	1.2
Mean value		12.0	6.5	2.9	3.2
$Ca(NO_3)_2$	0.5	15.2	8.1	3.3	3.1
	1.0	18.5	9.4	5.5	4.9
	1.5	23.4	10.2	6.9	5.9
	2.0	12.6	5.5	3.0	2.5
	3.0	9.8	2.4	1.6	1.0
Mean value		15.9	7.1	4.1	3.5
NH_4NO_3	0.5	13.6	7.3	3.9	4.1
	1.0	16.2	8.8	4.3	5.4
	1.5	21.9	11.4	7.8	7.3
	2.0	13.1	3.8	4.1	4.2
	3.0	9.1	2.0	2.4	3.5
Mean value		14.8	6.7	4.5	4.9
$CO(NH_2)_2$	0.5	13.9	7.5	3.9	3.4
	1.0	15.2	8.4	5.0	4.8
	1.5	18.9	9.4	7.1	6.2
	2.0	11.8	2.9	3.7	3.6
	3.0	7.9	1.2	1.4	1.9
Mean value		13.5	5.9	4.2	4.0
$LSD_{0.05}$		1.43	0.88	0.76	0.29

Taking into account the form of nitrogen present in fertilizers, average the highest lettuce yields were obtained when plants were fertilized with calcium and ammonium saltpetre, while the lowest ones resulted from fertilization with this element in the form of ammonium sulfate. The yields of lettuce fertilized with urea were of a medium size. Similar results were reported by [13], who used 5.5 g of nitrogen in the form of

ammonium saltpetre, which caused an increase in lettuce yield size in comparison with control treatment. The same authors proved that increased dose of nitrogen fertilizer brought about considerably smaller yield size.

The data present in Table 1 apparently prove that in the case of radish as well as of lettuce higher yields were also obtained in the spring. Considering average amounts of particular treatments it should be stated that generally, in the autumn the yields were nearly twice lower. This can be confirmed by the other authors [11], who, in their research on the effect of cultivation term on nitrates(V) content in radish roots, reported higher leaves mass from the spring cultivation and slightly lower – from the autumn cultivation. According to Kobryn [10] an important role is also played by the term of plants sowing. Earlier radish sowing did effect on obtaining higher yields of radish roots.

Noticeable influence on yield size had nitrogen dose. Initially, as the mentioned dose increased there was recorded significant increase in roots yield, but when the dose exceeded 1.5 $g \cdot pot^{-1}$ yield size did considerably diminish. It should be stated that there was no evidence of a significant effect of any nitrogen form on radish yield size, as average yields of roots from each experimental treatment were of similar values. The only exception was cultivation of this plant in the autumn, since there were recorded some tendencies of root yield to increase when ammonium saltpetre and urea were used as fertilizers.

Nitrogen fertilization did markedly effect on $N\text{-}NO_3$ content in cultivated plants. Nitrates(V) concentration in both plant species cultivated in the autumn was lower than the one featuring these vegetables cultivated in the spring, which confirms the conclusions by other authors. Buniak [14] reported that regardless the plants species definitely more nitrates(V) were present in them in the spring than in the summer, while Lis [9] reported that early cultivars of potato accumulate higher amounts of nitrates(V) than later cultivars. However, there do exist literature records with other results. Michalik and Szwonek [7] after Hermanowicz reported that in the experiment with spinach the mentioned author proved higher nitrates(V) content in plants cultivated in the autumn. Also Bram et al [15] obtained lower nitrates(V) content in lettuce cultivated in summer season in comparison with nitrates(V) content in plants cultivated in the autumn. In our research nitrates(V) content could be, to high extend, modified by photoperiod conditions in the course of plant vegetation.

The data shown in Figs. 1–4 apparently prove that nitrate(V) form of nitrogen in both species of cultivated plants increased as nitrogen fertilizer dose increased, regardless particular forms of nitrogen present in fertilizer applied.

Lettuce cultivated in the spring contained higher quantity of $N\text{-}NO_3$ than in autumn season (Figs. 1–2). Yet the most significant influence on nitrates(V) accumulation by this vegetable, regardless its cultivation term, had nitrogen dose and the form this component was used. In both terms of lettuce cultivation the lowest amount of $N\text{-}NO_3$ in this plant was recorded for its fertilization with ammonium sulfate, while the highest quantities of nitrogen occurred after fertilization with ammonium and calcium saltpetre. Fertilization with urea caused nitrates(V) accumulation ranging average values, yet in this case attention should be paid to much higher content of mineral nitrogen in lettuce

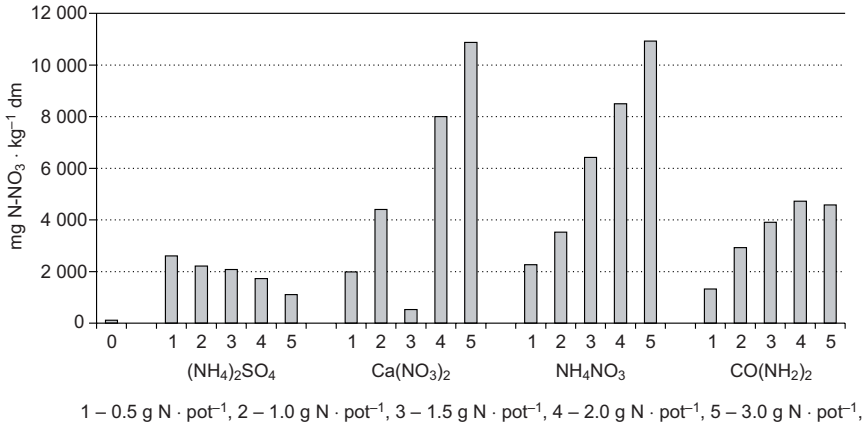

Fig. 1. N-NO_3 content in spring-cultivated lettuce

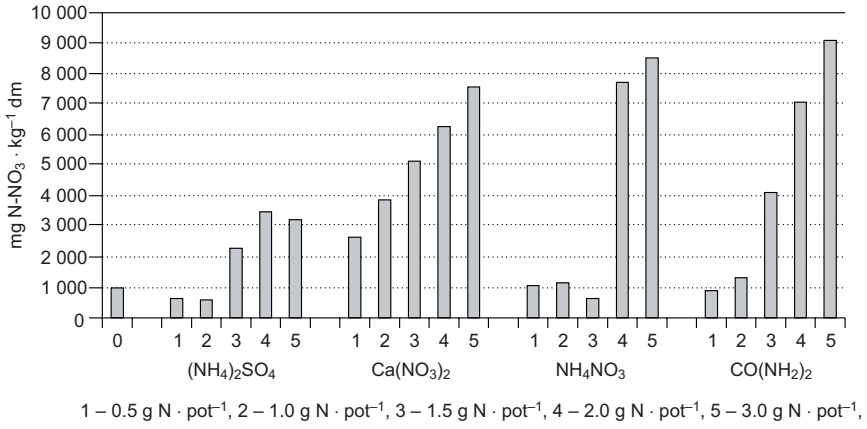

Fig. 2. N-NO_3 content in autumn-cultivated lettuce

fertilized with urea in the autumn than in the spring. The latter phenomenon was probably observed due to slow release of nitrogen as a result of the process of fertilizer hydrolysis.

Apart from the above results, in spring-cultivated lettuce there was observed relatively proportional increase in N-NO_3 according to increasing amount of nitrogen in soil, while in the same plant cultivated in later term significant increase in this form of nitrogen was noticeable only at nitrogen doses ranging 2 and 3 g N · pot^{-1}. These rather low contents of N-NO_3 in lettuce, observed especially for plants fertilization with nitrogen in the amount of 1.5 g N · pot^{-1}, could result from dilution of this component as generally in our investigation at that dose there were recorded the highest plant yields.

Similar results were obtained in the experiments by Kalembasa and Deska [13], who proved that gradually increasing doses of ammonium saltpetre brought about consider-

able increase in nitrates(V) amount in lettuce leaves. Also in research by Zalewski [16], lettuce fertilized with higher nitrogen doses accumulated higher quantities of nitrates(V). Michalik [17, 18] on the basis of pot experiment, stated that nitrates(V) content in lettuce increased according to increasing doses of nitrogen in earlier terms of cultivation. According to Barczak and Cwojdzinski [19] the increase in nitrogen dose causes increased uptake of this element by plants and, therefore its usability for protein synthesis is weaker, which results in highest contribution of nitrate(V) fraction in total the nitrate. As it was reported by Rogozinska et al [20] nitrates(V) content in mature potato tubers increased proportionally to increased doses of mineral nitrogen fertilizers.

The results shown in Figs. 3 and 4 confirm previous observations that higher amounts of nitrates(V) were accumulated in radish roots in the autumn, and concentration of this form increased with nitrogen dose. The highest increase in $N\text{-}NO_3$ content in radish roots in comparison with the amount of this nitrogen form assayed in cultivated

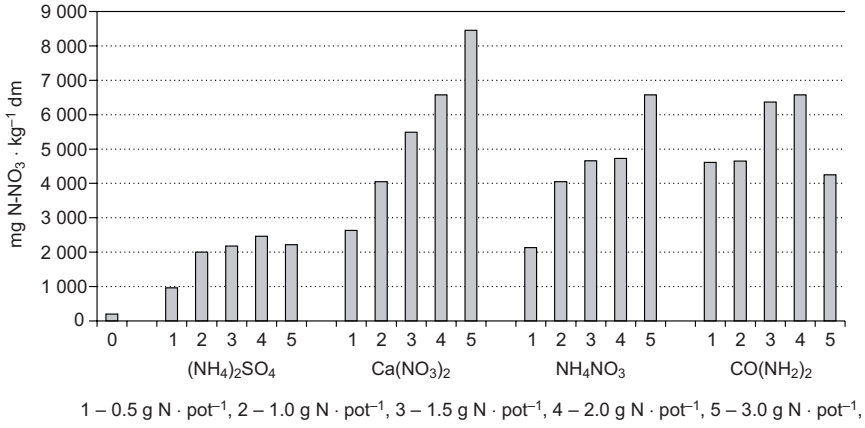

Fig. 3. $N\text{-}NO_3$ content in radish roots cultivated in the spring

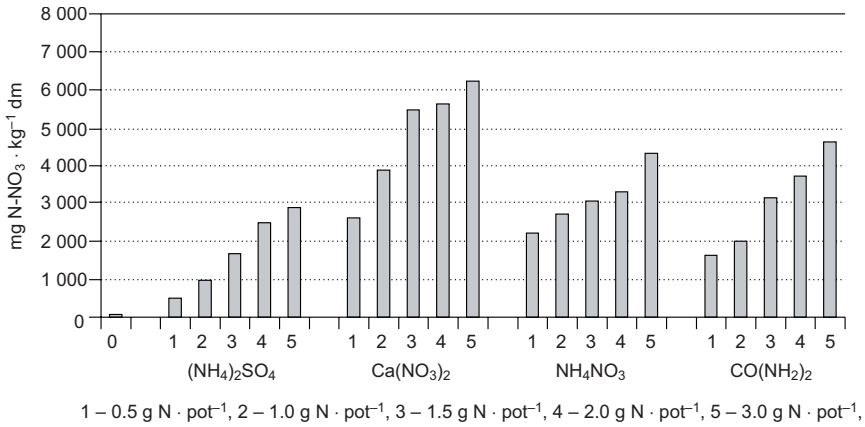

Fig. 4. $N\text{-}NO_3$ content in radish roots cultivated in the autumn

plants originating from control treatment was observed after application of ammonium and calcium sulfate, while the lowest one occurred after plant fertilization with ammonium sulfate. As far as this vegetable is concerned, it should be stressed that significant influence of amide form of nitrogen on the increase in nitrates(V) accumulation takes place regardless its cultivation term. The results obtained in our research were, in most cases, in agreement with those found in the literature, among others by Jagiello et al [21] who reported that nitrates(V) content in beet and carrot roots depended on fertilizer dose and kind and it increased as the amount of added fertilizer increased. Czekala [22] proved the effect of fodder beet cultivar on nitrates(V) accumulation in its roots and leaves. Michalik [17, 18] found that the form of nitrogen introduced effected on nitrates(V) content in vegetables and that fertilizers featuring slow release of nitrogen caused the increase in plant nitrates(V) content to a lower degree. Lettuce fertilized with ammonium nitrate(V) characterized higher nitrates(V) content as compared with lettuce fertilized with urea. Similarly, Goralski and Kaminska-Dudek [23], comparing the effect of ammonium saltpetre and urea, reported that ammonium nitrate(V) content in plant material was always higher after application of ammonium saltpetre than after urea fertilization. Jurgiel-Malecka and Suchorska--Orlowska [24] stated that the kind of fertilizer applied (urea, ammonium saltpetre, calcium saltpetre) did not significantly effect on nitrate(V) content in leaves of bulb plants subjected to examination. Kalembasa and Deska [13] comparing the effect of nitrogen used in vermicompost, manure and mineral fertilizers on yield, total nitrogen content and nitrates(V) content in lettuce leaves, reported that increased doses of ammonium saltpetre did considerably increase nitrates(V) content, while in the case of vermicompost $N\text{-}NO_3$ concentration showed only slight increase. Similar results were obtained in our investigation – the lowest nitrates(V) content was recorded in plants cultivated on the treatments where ammonium sulfate was applied. According to Michalik and Borkowski [6] physiologically acid character of ammonium sulfate could markedly lower medium pH which in turn could influence on the increase in nitrates(V) content.

In the conditions of investigation conducted, regardless cultivation term, higher amounts of nitrates(V) were accumulated by lettuce than by radish. Considering total nitrogen and mineral nitrogen content in soil, it was reported that as nitrogen dose increased its content in surface soil layer also increased and this amount was dependent on the kind of nitrogen fertilizer used and on cultivated plant species. Higher quantities of mineral nitrogen contained soils fertilized with ammonium saltpetre, calcium saltpetre and ammonium sulfate, than soil fertilized with urea. N-mineral content in soil after lettuce and radish cultivation on particular combinations was similar. Total nitrogen content in soil was related to cultivated plant species. The highest quantity of this component was detected in soils after radish cultivation.

$N\text{-}NO_3$ contribution to mineral nitrogen depended on the form of fertilizer applied. The highest amounts of this nitrogen form was determined in soils fertilized with calcium and ammonium saltpetre, as well as with urea, while the lowest one – after the use of ammonium sulfate (Figs. 5, 6). After cultivation of plants fertilized with calcium

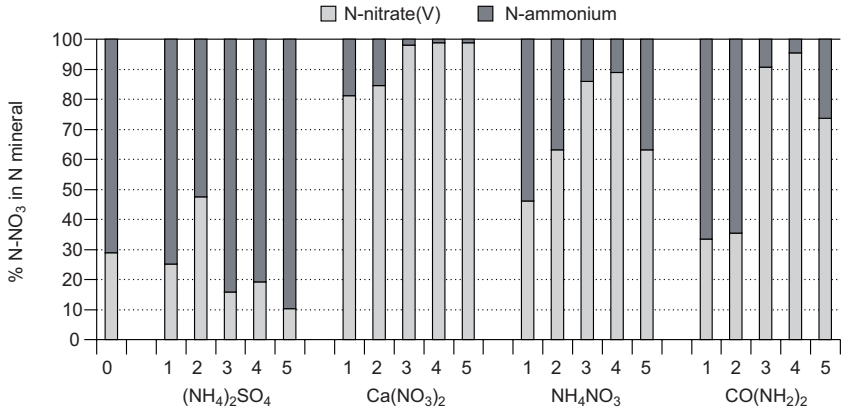

Fig. 5. Percentage contribution of N-NO_3 in mineral N in soil after lettuce cultivation

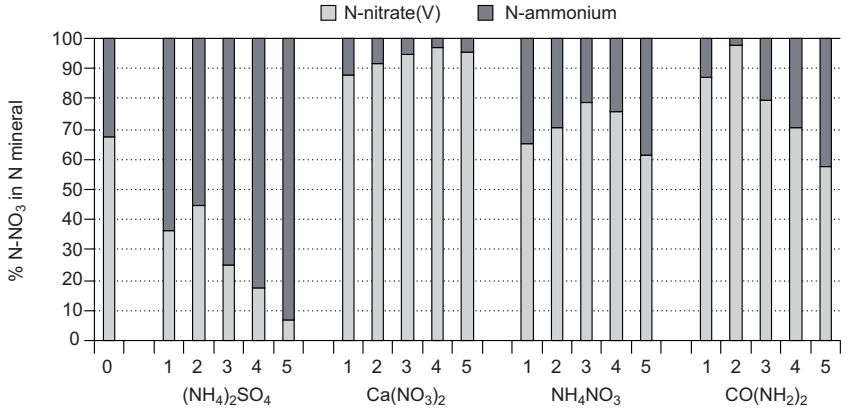

Fig. 6. Percentage contribution of N-NO_3 in mineral N in soil after radish cultivation

saltpetre the contribution of soil N-NO_3 in mineral nitrogen content was high and it ranged, depending on particular species cultivated, from 75 to 94 %.

The use of ammonium saltpetre had caused decrease in content of N-NO_3 accumulation in soil. In soils, where calcium saltpetre was applied, after completing the experiment was 50 to 70 % more of N-NO_3 depending on cultivated plant. Similar quantities of this nitrogen form were found in soils fertilized with urea. The use of ammonium saltpetre was also decisive regarding N-NO_3 accumulation in soil, although these amounts were considerably lower, in comparison with calcium saltpetre and not exceeding the range of about 50 to 70 %, according to plant species cultivated. Similar quantities of this nitrogen form were found in soils fertilized with urea.

The lowest amount of N-NO_3 in relation to the dose of mineral nitrogen after plant harvesting were determined in soils fertilized with ammonium sulfate. These values

ranged from 10 to 30 % and nitrate(V) nitrogen was the remaining part. In all the cases discussed the contents of nitrate(V) nitrogen were dependent on fertilizer dose and they were the higher the higher dose was applied. According to Ciecko et al [25] nitrogen fertilization caused higher concentration of ammonium and nitrate(V) nitrogen in soil solution. The authors, on the basis of long-term experiments, proved that under the influence of high-dose nitrogen fertilization there occurred a tendency in soils to increase contribution of nitrate(V) nitrogen in mineral nitrogen.

Conclusions

1. Out of two vegetable species subjected to examination lettuce accumulated higher amounts of nitrate(V) nitrogen than radish. In both of plants the highest contents of $N\text{-}NO_3$ was determined after application of highest doses of this element.

2. Higher contents of nitrates(V) in the lettuce leaves and radish roots were determined when cultivation took place in the spring. In the autumn nitrates(V) contents showed decreased values.

3. Regardless plant species, the highest amount of nitrates(V) were accumulated by plants fertilized with calcium and ammonium saltpetre, while the lowest ones belonged to vegetable fertilized with ammonium sulfate.

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WPŁYW DAWKI I FORMY AZOTU NA ZAWARTOŚĆ AZOTANÓW(V) W WYBRANYCH GATUNKACH WARZYW

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Abstrakt: Celem prezentowanej pracy była ocena wpływu stosowania wzrastających dawek różnych form azotu na gromadzenie się azotanów(V) w sałacie i korzeniach rzodkiewki. Badania realizowano poprzez ścisłe doświadczenia wegetacyjne, które prowadzono w latach 2003–2005 w hali wegetacyjnej. W każdym roku badań wiosną i w okresie jesiennym oba gatunki roślin nawożono azotem w ilości; 0,5; 1,0; 1,5; 2,0; i 3,0 g $N \cdot wazon^{-1}$, stosując go w postaci $(NH_4)_2SO_4$, $Ca(NO_3)_2$, NH_4NO_3 oraz $CO(NH_2)$. Doświadczenie założono na glebie lekkiej o odczynie słabo kwaśnym, niskiej zawartości potasu, średniej fosforu oraz wysokiej magnezu. Wpływ dawki i formy azotu oceniono analizując masę plonów uprawianych roślin, zawartość azotu ogólnego oraz azotu azotanowego(V). W glebach po zakończeniu badań określono zawartość azotu mineralnego. Wykazano, że plony zarówno sałaty, jak i rzodkiewki wzrastały w miarę zwiększania dawki azotu do 1,5 g $N \cdot wazon^{-1}$. Najbardziej plonotwórczo w przypadku sałaty działała saletra wapniowa, natomiast w przypadku rzodkiewki saletra amonowa. Znacznie większe plony obu roślin z tych samych obiektów zebrano, uprawiając je w okresie wiosennym. Najwyższą koncentrację azotu azotanowego(V) oznaczono w obu roślinach wówczas, gdy nawożono je najwyższą dawką azotu, jednak zawsze większe zawartości tej formy azotu stwierdzano w sałacie niż rzodkiewce. Mniej azotanów(V) w każdym z badanych gatunków oznaczono wiosną niż jesienią. Niezależnie od gatunku, najwięcej azotanów(V) gromadziły rośliny nawożone saletrą wapniową i amonową, a najmniej, gdy w ich uprawie stosowano siarczan amonu.

Słowa kluczowe: nawożenie azotem, formy azotu, azot azotanowy(V), termin uprawy, sałata, rzodkiewka