ACTA AGROBOTANICA
Vol. 57, z. 1-2 – 2004
s. 49–55

Ion exchanger BIONA 312 as a component of soils polluted with nickel in cultivation of cucumber (*Cucumis sativus* L.)

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(Received: 5.03.2004)

Summary

The objective of the studies undertaken was to assess the possibility of ion exchange substrate BIONA 312 use for nickel bioavailability limitation in cucumber (*Cucumis sativus* L.) 'Hermes' cv. as determined on the ground of chlorophyll and Ni content. BIONA 312, regarding the chemical composition, is a mixture of strongly acid cation exchanger KU-2x8 and polyfunctional weakly alkaline anion exchanger EDE-10P. The experiment was differentiated in regard to nickel and ion exchanger content. The following doses of Ni (in the form of $NiSO_4$) were introduced: 0, 30 or 75mg $Ni \cdot dm^{-3}$ of the substrate. BIONA 312 was added to the medium in the following doses: 0, 2 or 5% of substrate volume. Together with Ni dose increase in the medium there was recorded a significant increase of this metal concentration in the cucumber biomass. Nickel in the amount 30 $mg \cdot dm^{-3}$ did not affect considerably the changes in any of chlorophyll form, but a dose 75mg $Ni \cdot dm^{-3}$ has caused a significant decrease in chlorophyll „a" concentration in cucumber leaves. Simultaneously with the increase in the nickel content in the nutritive environment the decrease in the value of organic mass productivity coefficient was observed. The introduction of 5% ion exchange substrate BIONA 312 into the medium containing nickel in the amount 30 or 75 $mg \cdot dm^{-3}$ induced a significant growth of the studied chlorophyll fractions in the cucumber leaves. BIONA 312 introduced to the environment contaminated with nickel in the amount of 30 or 75 $mg \cdot dm^{-3}$ has significantly reduced Ni content in the cucumber biomass simultaneously increasing participation of roots in organic mass production. More efficient for the reduction of harmful Ni effect on the cucumber plants turned out to be introduction of ionite sorbent BIONA 312 at the dosage 5% than 2%.

Key words: cucumber (*Cucumis sativus* L.), nickel, ion exchange substrate BIONA 312, chlorophyll content

INTRODUCTION

Increasing amounts of nickel available in a substrate result in the growing uptake of this metal and as consequence, induce many abnormalities in the physiological processes and plant morphogenesis. As a result of this productivity drop is recorded (Pillay et al., 1996, Pandey and Sharma, 2002). As Drążkiewicz (1994) and Krupa, Baszyński (1995) hold, the photosynthesis process belongs to the basic physiological processes disturbed by nickel. A reason for lower intensity of photosynthesis due to nickel contamination prove to be not only changes in the chloroplasts ultrastructure or inhibition of the QB enzyme affecting PS II directly but chlorophyll concentration decrease as well (King-Diaz et al., 1995, Krupa and Baszyński, 1995). Hence one of the main problems of the gardeners and horticultural sciences concentrates on new methods and technologies aiming at phytotoxicity reduction of metals presented in plants environment. One of the ways is phytostabilization, that is limitation of metal mobility and migration in the plant nutritive environment. The objective of the studies undertaken was to assess the possibility of ion exchange substrate BIONA 312 use for nickel bioavailability limitation in cucumber (*Cucumis sativus* L.) 'Hermes' cv. as determined on the ground of chlorophyll as well as Ni content. BIONA 312, regarding the chemical composition, is a mixture of strongly acid cation exchanger KU-2x8 and polyfunctional weakly basic anion exchanger EDE-10P. Absorption capacity of anion exchanger EDE-10P was 3.5 $mmol \cdot g^{-1}$.

MATERIAL AND METHODS

Ionite substrate BIONA 312 is a mixture of ion-exchange substrate BIONA 112 (56%) and clinoptylolite (44%) (Soldatov et al., 1997, Chomczyńska et al., 2002). BIONA 312 contains the following quantities of nutrients ($g \cdot kg^{-1}$ medium): N-11.21, P-3.41, K-17.60, Ca-22.24; Mg-4.38, S-6.09, Fe-2.23., Mn-0.220, Cu-0.064, Zn-0.057, Co-0.015, Mo-0.044, B-0.110, Cl-3.900, Na-1.380; the medium pH was equal 6.5-7.0. The experiment was conducted in the pots of $3dm^3$ capacity. Control was made by the substrate composed of hortisol and sand at the rate 2:1: The chemical composition of the hortisol water extract included: N-22.54, P-0.05, K-52.39, Ca-189.73, Mg-9.19, S-17.73, Fe-10.89, Cl-22.90, Na-11.79 $mg \cdot dm^{-3}$ and 47.8% humus. The experiment was differentiated regarding nickel content and quantity of ion exchange substrate BIONA 312. Nickel was applied as $NiSO_4 \cdot 7H_2O$ at the following doses: 0; 30 or 75 mg $Ni \cdot dm^{-3}$ medium, whereas the ionite substrate was introduced in the quantities making 0, 2 or 5% of medium volume. The mineral nutrition was supplemented taking into account the chemical composition of the substrate and nutrition requirements. At all of the experimental treatments the nutrient were supplemented up to: N-450 (NH_4NO_3 and KNO_3), K-400 (KNO_3 and KH_2PO_4), Ca-700 ($CaCO_3$), Mg-200 ($MgCl_2$), P-180 (KH_2PO_4) mg per pot. At florescence there was determined chlorophyll „a" and chlorophyll „b" content in the 7th leaf from below by Arnon method. For the sake of considerable participation of roots in organic mass production as well as taking into account exposition of these organs on stressful factor (nickel) and usage of ionite sorbent as the component of the substrate the coefficient of organic mass productivity i.e. dry mass of roots /dry mass of shoots ratio has been calculated. Nickel content was established in the dry plant material using atomic absorption spectrometry method. The data concerning chlorophyll and nickel content were analysed statistically computing the least significant difference ($LSD_{0.05}$).

RESULTS AND DISCUSSION

Ni presence in cucumber biomass in the control conditions (0 mg Ni·dm^{-3}) proves the natural Ni presence in the hortisol used in the experiment. Together with Ni dose increase in the medium there was recorded a significant increase of this metal concentration in the cucumber, especially in roots. BIONA 312 applied to the environment contaminated with nickel, in particular a dose 5%, has significantly reduced Ni content in the cucumber biomass (Table 1). Although nickel in the amount 30 mg·dm^{-3}

Table. 1. Nickel content in cucumber plants

Differential factor BIONA 312 % of the substrate	Ni mg·dm^{-3}	Nickel content (mg·kg^{-1} DW) Shoots	Roots	Mean for BIONA 312 Shoots	Roots	Mean for Nickel Shoots	Roots
0		0.95	4.15	5.33	89.08		
2	0	1.65	3.99	4.38	61.91	1.15	3.74
5		0.85	3.09	2.61	82.41		
0		4.85	66.25				
2	30	3.95	50.75			4.20	60.37
5		3.80	64.10				
0		10.20	196.85				
2	75	7.55	131.00			6.98	169.30
5		3.18	180.05				
$LSD_{0.05}$ for		BIONA 312·Ni		BIONA 312		Ni	
		1.07	11.83	0.50	4.82	0.50	4.82

did not affect considerably the changes in any of chlorophyll form content, whereas a dose 75 mg Ni·dm^{-3} has caused a significant decrease in chlorophyll „a" concentration (Table 2). The reasons for chlorophyll content reduction due to Ni may lie in the enhanced activity of chlorophyllase in the plants treated with nickel as well as sensitivity of other enzymes of porphyrin synthesis tract and in inhibition of dehydrogenase synthesis of delta-aminolevulinic acid (ALAD, E.C.4.2.1) – the enzyme contributing into synthesis of the assimilative pigments (Drążkiewicz, 1994). Pandey and Sharma (2002) also confirmed a drop of chlorophyll content in another plants species exposed to heavy metals (Co^{2+}, Ni^{2+} and Cd^{2+}) resulting either from a decrease of ferric-porphyrin enzyme activity – catalase and peroxidase or from diminished iron availability for chlorophyll biosynthesis being due to limited iron uptake by heavy

Table. 2. Chlorophyll content in cucumber leaves (mg·g^{-1} fresh weight)

Differential factor BIONA 312 %	Ni mg·dm^{-3} of the substrate	Chlorophyll „a"	Chlorophyll „b"	Chlorophyll „a+b"	Mean for BIONA 312 Chlorophyll „a"	„b"	„a+b"	Mean for Nickel Chlorophyll „a"	„b"	„a+b"
0		1.7080	0.4970	2.2050	1.5380	0.4490	1.9870			
2	0	1.9715	0.5600	2.5315	1.7122	0.5073	2.2195	1.9820	0.6013	2.5833
5		2.2665	0.7470	3.0135	2.0615	0.6330	2.6945			
0		1.6420	0.4855	2.1275						
2	30	1.6515	0.4445	2.0960				1.7715	0.5128	2.2843
5		2.0210	0.6085	2.6295						
0		1.2640	0.3645	1.6285						
2	75	1.5135	0.5175	2.0310				1.5582	0.4752	2.0333
5		1.8970	0.5435	2.4405						
	$LSD_{0.05}$ for	BIONA·Ni			BIONA			Ni		
		0.3162	0.1753	0.8740	0.1290	0.0715	0.3565	0.1290	0.0715	0.3565

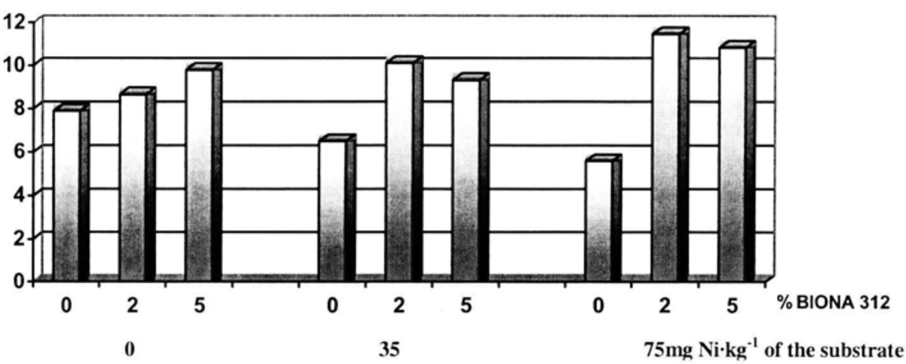

Fig. 1. Coefficient of organic mass productivity

metals mentioned. It has been shown that increasing nickel doses in the medium (30 and 75 mg×dm^{-3}) resulted in increase of the coefficient of the organic mass productivity respectively by 8 and 10% (Figure 1). It confirms previous studies under nickel influence on changes of root physiological indices. Results of this experiments indicated that nickel significantly decreased biological activity of roots (Szymańska and Matraszek, 1996, Matraszek, 1999). Stankow (1968) adduces studies of many authors holding that depending on plant species and nutritive environment characteristics there is a wide range of the value of the coefficient of organic mass productivity (0.03 – 13.5). So the obtained in the presented work values of the coefficient of organic mass productivity (5.75 – 11.46) goes into the top range of this parameter (Figure 1). The application of the ionite substrate BIONA 312 in the amount making 5% of the medium volume into the control environment (Ni – 0 mg·dm^{-3}) has caused the raise of the value of the coefficient of organic mass productivity as well as a significant increase of both chlorophyll forms contents in the cucumber (Table 2, Figure 1).

The introduction of 5% ion exchange substrate BIONA 312 into the medium containing nickel in the amount 30 or 75 $mg \cdot dm^{-3}$ induced a significant growth of the studied chlorophyll fractions in the cucumber leaves. The concentration changes of chlorophyll „a" and „b" maintained at the same level, at increase of these chlorophyll forms – 24 and 50% for nickel doses 30 and 75 $mg \cdot dm^{-3}$. The value of the coefficient of organic mass productivity informing about participation of roots in organic mass productivity has also increased. Thus, BIONA 312 increased nickel content in roots i.e. organs in which nickel content in comparison with aboveground parts was very high as well as increased chlorophyll content in leaves. As a consequence ionite substrate raised the value of the coefficient of organic mass productivity increasing root participation in organic mass production. Irrespective a substrate contamination level with nickel more efficient for the reduction of harmful Ni effect on the cucumber plants turned out to be introduction of ion exchanger BIONA 312 at the dosage 5% than 2%. Generally, the better results were obtained when ionite sorbent was applied at the highest nickel dose studied 75 mg $Ni \cdot dm^{-3}$ as compared to 30 mg $Ni \cdot dm^{-3}$ (Tables 1, 2; Figure 1).

On the grounds of the obtained results, BIONA 312 can be included among the compounds fit for phytostabilization and reducing nickel bioavailability. However, after the plant have been removed from the substrate nickel is still detectable there and when the soil conditions are changed it may be released and become mobile. This method is likely to be useful to prevent soil from degradation and metals spreading but the efficient cleaning-up of the plant nutritive environment is long-lasting indeed, because metal still remains in the medium and when the soil conditions are changed it may by released and become mobile that means available for plants.

Considering all results obtained in this study it may be concluded that:

1. Together with nickel dose increase in the medium a significant increase of this metal concentration in the cucumber, especially in roots, was recorded.
2. Nickel in the amount 30 $mg \cdot dm^{-3}$ did not affect considerably the changes of chlorophyll „a" and chlorophyll „b" content in cucumber 'Hermes' cv. plants, whereas a dose 75 mg $Ni \cdot dm^{-3}$ has caused a significant decrease especially in chlorophyll „a" concentration.
3. The introduction of 5% ion exchange substrate BIONA 312 into the medium containing nickel in the amount 30 or 75 $mg \cdot dm^{-3}$ induced a significant increase of chlorophyll „a" and chlorophyll „b" content in the cucumber leaves.
4. BIONA 312 applied to the environment contaminated with nickel, in particular a dose 5%, has significantly reduced Ni content in the cucumber biomass.
5. Together with the increase in the nickel content in the nutritive environment the decrease in the value of organic mass productivity coefficient was observed. Introduction of BIONA 312 the medium contaminated with nickel increased participation of roots in organic mass production.
6. Ion exchanger BIONA 312 as an component of nickel polluted soils gives positive effects in cucumber 'Hermes' cv. cultivation.

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Substrat jonitowy BIONA 312 jako komponent gleb skażonych niklem w uprawie ogórka (*Cucumis sativus* L.)

Streszczenie

Celem podjętych badań była ocena substratu jonitowego BIONA 312 w ograniczeniu bioprzyswajalności niklu w uprawie ogórka (*Cucumis sativus* L.) odm. Hermes określana na podstawie zawartości w biomasie Ni oraz chlorofilu. BIONA 312 z chemicznego punktu widzenia jest mieszaniną silnie kwaśnego kationitu KU-2x8 i polifunkcyjnego słabo zasadowego anionitu EDE-10P o pojemności chłonnej $3.5 mmol \cdot g^{-1}$, nasyconego w odpowiednich proporcjach biopierwiastkami. Eksperyment zróżnicowano pod względem zawartości niklu (0, 30 lub 75 mg $Ni \cdot dm^{-3}$ podłoża ($NiSO_4 \cdot 7H_2O$) i sorbentu jonitowego BIONA 312 (0, 2 lub 5% objętości podłoża). Wraz ze wzrostem dawki Ni w podłożu istotnie zwiększała się koncentracja tego metalu w biomasie ogórka. Nikiel w ilości 30 $mg \cdot dm^{-3}$ nie wpłynął w istotny sposób

na zmiany w zawartości poszczególnych frakcji chlorofilu, natomiast dawka 75mg Ni·dm^{-3} spowodowała istotny spadek koncentracji chlorofilu, zwłaszcza chlorofilu „a" w liściach ogórka. Wraz ze wzrostem zawartości niklu w środowisku odżywczym zmniejszał się współczynnik produkcyjności masy organicznej. Aplikacja 5% substratu jonitowego BIONA 312 do podłoża zawierającego nikiel w ilości 30 lub 75 mg·dm^{-3} wpłynęła na istotny wzrost zawartości analizowanych frakcji chlorofilu w liściach ogórka. BIONA 312 aplikowana do skażonego niklem środowiska w sposób istotny zmniejszyła zawartość Ni w biomasie ogórka równocześnie zwiększając udział korzeni w tworzeniu masy organicznej. Wprowadzenie wymieniacza jonowego BIONA 312 do podłoża skażonego niklem było korzystniejsze (dało lepszy efekt) w przypadku wyższej (5%) dawki jonitu.