J.K.A.U.: Sci., vol. 4, pp. 37-43 (1412 A.H./1992 A.D.

Effect of Nickel on the Content of Carbohydrate and Some Minerals in Corn and Broad Bean Plants

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ABSTRACT. In a pot experiment, seeds of corn and broad beans were planted in sandy soil, after soaking in different levels of Ni (as Ni-sulphate) ranged between 25 and 400 ppm. Germination percentage of broad beans seeds soaked in high levels of Ni showed an extreme decline. On the other hand, germination of corn were not particularly affected.

Lower levels of Ni induced a considerable increase in the dry matter, carbohydrate content and some minerals (Fe, Mn, Zn) in corn. These tested parameters were reduced with increasing nickel concentration in the soaking solution. On the other hand, the tested parameters were generally reduced in case of faba beans, and reduction was more pronounced on higher nickel levels.

Introduction

The problem of toxic heavy metals had recently been given much attention, especially after the recognization of soil pollution and the widespread of industrialization and urbanization. Nickel is one of the most toxic element to plant. Kirkham[1] reported that Ni is eight times as toxic to plants as Zn. Some plant species are tolerant to Ni toxicity, and the accumulation of large amount of Ni in their shoots produces no adverse effects[2]. Connen and Anderson[3] reported that Ni content in healthy plants

should not exceed 1 ppm in dry matter. Some investigators[4-6] noticed the stimulatory effects of Ni at low concentration, as it enhanced plant growth, and increased dry matter and yield. On the other hand, the toxic concentrations of Ni were found to cause chlorosis, which was followed by necrosis, complete blackening, death of young leaves, and apical buds beside a depression in plant growth and a reduction in some nutrients uptake[6-9]. It seems that little attention has been paid to biochemical response of Ni phytotoxicity. The aim of the present work was to study the effect of soaking broad beans and corn seeds in Ni on the carbohydrate fractions and some nutrients content in plants.

Material and Methods

Seeds of corn (*Zea maize* var. Giza 2) and broad beans (*Vicia faba* var. Giza 2) were soaked in Ni-sulphate solutions at the concentrations of 0, 25, 50, 100, 200 and 400 ppm for 24 hours, then washed with distilled water and air dried. Seeds were then planted in plastic pots filled with 5 kg sandy soil each obtained from Ismailia Province. Soil showed that the DTPA extractable Fe, Mn, Zn, and Ni were 4, 4, 0.1 and 0 ppm, respectively. NPK requirements, were added as 2 g ammonium sulphate and 1 g of potassium dihydrogen phosphate per pot for corn plant, while 0.5 g of ammonium sulphate, 2 g of superphosphate and 0.5 g of potassium sulphate/pot had been used for faba beans plant. Germination percentage of seeds of both plants were determined following the international rules of seed testing[10]. Seedlings were thinned to leave 5 and 4 plants per pot for corn and broad beans, respectively. At the end of the experimental time, corn (30 days old) and broad bean (45 days old), shoots were carefully harvested, dried at 70°C, and the dry weights were recorded.

Total carbohydrates were extracted using sulphuric acid in sealed tube in electric oven at 100°C for 24 hrs. Total sugars were extracted by 80% ethyl alcohol for 6 hr. Total carbohydrates and total sugars were determined colorimetrically by the method described by Smith *et al.*[12] Reducing sugars were determined in the ethanolic extract using the method listed in the A.O.A.C.[12] Mineral contents (Fe, Mn, and Zn) in shoots, and Ni concentration in seeds, were determined by the dry ashing method using atomic absorption spectrophotometer Perkin Elmer 2380.

Results and Discussion

1. Germination Percentage

Data presented in Table 1 clearly shows that seeds of broad beans has the capacity to absorb large amounts of Ni was compared to corn seeds. Data also demonstrated that Ni had no effect on germination percentage of corn seeds. On the other hand, germination of broad bean seeds was gradually inhibited by increasing Ni concentration, *i.e.* 50, 100 and 200 ppm inhibited germination by 10, 50 and 75%, respectively. It can be noticed that germination was completely inhibited by 400 ppm. The decline in germination percentage at high concentrations of Ni may be attributed to the toxic effect on the enzymatic systems, which influence the different metabolic processes needed to complete seed germination.

TABLE Accumulated nickel, germination percentage, and dry weight of corn and faba beans as affected by seed soaking in Ni solution.

Nickel in soaking soil (ppm)	Accumulated nickel in seeds (ppm)		Germination %		Dry weight g/pot	
	Corn	broad beans	Corn	broad beans	Corn	broad beans
0	0.4	1.0	100	100	10.8	5.7
25	4.5	8.0	100	100	13.9	6.1
50	6.0	18.0	100	90	13.3	6.1
100	9.0	20.0	100	50	12.1	5.7
200	10.0	24.0	100	25	12.6	4.0
400	11.0	30.0	95	–	11.4	–
L.S.D. at 0.01					2.15	N.S.

2. *Dry Matter Production*

Soaking needs in the examined concentrations of Ni induced a statistically significant increase in dry matter of corn. This increase was significant at the levels 25 and 50 ppm. On the other hand, no significant differences were found with broad beans (Table 1). Several authors reported the stimulatory effect of Ni application in enhancing plant growth[5-7,13]. Application of Ni at low levels had no significant effect on dry weight of broad bean shoots. The reduction in growth was associated with chlorosis and necrosis in bean at 200 ppm, while the plant completely died at 400 ppm.

3. *Carbohydrate Fractions*

Soaking of seeds in different concentrations of Ni had a significant effect on carbohydrate contents in both corn and broad bean. In this concern, soaking corn seeds up to 50 ppm Ni solutions increased the total carbohydrate content, however, soaking in 100, 200 and 400 ppm depressed it. Level of 50 ppm was the most promising concentration as it increased the total carbohydrates with about 17%, however, the concentration of 400 ppm was the most retarding as it decreased the total carbohydrates in corn plant with about 22% as compared to control. Also, data presented in Table 2 shows that the effect of Ni application on total reducing and nonreducing sugars in corn was parallel to its effect on the total carbohydrate contents with few exceptions, especially for nonreducing sugars.

All levels of Ni in soaking solutions gradually decreased all carbohydrate fractions in broad bean seeds (Table 2). The observed stimulation in the low levels of Ni on carbohydrates synthesis, in case of corn plant, may be attributed to an activation effect on the enzymatic systems connected with the carbohydrates' anabolism cycle. On the other hand, the observed decline in total carbohydrates with respect to the high levels of Ni may be due to its role on the enzymatic reactions related to the cycles of carbohydrates catabolism.

TABLE 2. Effect of seeds soaking in Ni solution on carbohydrate fractions (mg/1g, d. wt) in corn and broad bean shoots.

Carbohydrate Fractions	Ni conc in soaking solution (ppm)					
	0	25	50	100	200	400
	Corn					
Total carbohydrates	130.50	142.50	152.33	137.17	111.83	101.50
Total sugars	32.78	34.47	36.33	32.96	30.97	28.59
Reducing sugars	22.82	23.03	25.14	21.87	20.59	18.96
Non-reducing sugars	9.96	11.44	11.19	11.09	10.38	9.63
	broad bean					
Total carbohydrates	79.17	74.67	70.50	63.00	55.67	–
Total sugars	48.77	47.72	46.76	44.17	41.14	–
Reducing sugars	35.39	35.82	34.95	32.48	30.56	–
Non-reducing sugars	13.38	11.9	11.81	11.69	10.58	–

L.S.D. at 0.01	Corn	broad bean
Total carbohydrates	8.30	9.35
Total sugars	2.67	2.31
Reducing sugars	1.53	1.92

4. *Micronutrient Contents*

Data in Table 3 clearly shows that soaking in Ni solutions up to 50 ppm increased the absorption of Fe and Mn in both corn and broad bean plants, while higher soaking levels declined this absorption process. All the studied levels of Ni decreased Zn concentration in both corn and broad bean plants. The reduction in Zn uptake was associated with the apparition symptoms of Zn deficiency on both corn and broad bean plants, especially at the highest levels. These results are in agreement with Maclean and Dekker[14], Abdel Latif *et al.*[6]. More or less, similar results *could be* reported in regard to nutrients uptake which is apparently related to the reduced growth. From the abovementioned results, it could be deduced that Ni may increased the supply of some nutrients and reduce others. The former diversity may be due to Ni influence on the enzymatic reactions affecting the absorption of different elements. Hewitt[7], as well as Brown *et al.*[15] concluded that Ni should be added to the list of micronutrients essential for all higher plant growth.

Table 4 hows a positive correlation between dry weight and element content in both corn and broad beans. Both Fe and Mn showed a significant positive correlation with different carbohydrate fractions in corn plant, while Zn exhibited nonsignificant positive correlation. On the other hand, a negative correlation coefficient was found between Fe and carbohydrate contents in broad beans, but it was nonsignificant. Both Mn and Zn contents were significant positively correlated with carbohydrate content in broad beans.

From the above-mentioned discussion, it could be deduced that both corn and faba beans plants showed different response to Ni application with respect to the different

TABLE 3. Effect of seeds soaking in Ni solution on micronutrient contents of corn and broad bean shoots.

Micronutrients	Ni concentration in solution (ppm)											
	0		25		50		100		200		400	
	Conc. ppm	uptake mg/pot	Conc. ppm	uptake mg/pot	Conc. ppm	uptake mg/pot	Conc. ppm	uptake mg/pot	Conc. ppm	uptake mg/pot	Conc. ppm	uptake mg/pot
						Corn						
Iron	283	3.03	308	4.16	313	4.03	273	3.27	244	3.05	234	2.66
Manganese	117	1.25	122	1.70	122	1.6	98	1.17	87	1.08	77	0.88
Zinc	32.0	0.36	32.0	0.41	31.7	0.42	30.5	0.36	28.3	0.35	28.3	0.33
						broad bean						
Iron	450	2.55	493	3.01	51.3	3.27	518	3.97	507	2.02	–	–
Manganese	63	0.36	67	0.41	67	0.41	60	0.34	60	0.24	–	–
Zinc	60.8	0.35	60.8	0.37	60.7	0.37	38.3	0.22	38.3	0.15	–	–

L.S.D. at 0.01	Iron		Manganese		Zinc	
	Conc.	uptake	Conc.	uptake	Conc.	uptake
Zea maize	N.S.	N.S.	26.02	0.411	N.S.	N.S.
Faba beans	N.S.	N.S.	N.S.	N.S.	10.76	0.086

TABLE 4. Correlation coefficients between mineral contents, dry weight and carbohydrates contents as affected by Ni soaking.

Element	Dry weight	Total carbohydrates	Total sugars	Reducing sugars	Nonreducing sugars
			Corn		
Fe	0.567	0.959	0.958	0.948	0.760
Mn	0.369	0.839	0.835	0.849	0.591
Zn	0.366	0.494	0.489	0.582	0.100
			broad bean		
Fe	0.037	–0.527	–0.429	–0.001	0.002
Mn	0.571	0.958	0.924	0.885	0.854
Zn	0.713	0.807	0.833	0.897	0.547

studied parameters. Nickel showed decline in germination percent and impairement in carbohydrates synthesis in broad beans rather than corn plants. On the other hand, the stimulative effect of low levels was more pronounced in enhancing the dry matter and mineral contents of corn as compared to those in broad bean plants. Worth of consideration to mention that broad beans was more sensitive to Ni toxicity rather than corn plant which showed more tolerant to the studied Ni levels.

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تأثير النيكل على محتوى الكربوهيدرات وبعض العناصر المعدنية في كلٍّ من نباتي الذرة الشامية والفول البلدي

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مركز البحوث الزراعية بجمهورية مصر العربية ، و *كلية العلوم ، جامعة الملك عبد العزيز بجدة ، المملكة العربية السعودية ، **هيئة الطاقة الذرية بجمهورية مصر العربية

المستخلص . في تجربة أصص ، تم نقع بذور كل من الذرة الشامية والفول البلدي في تركيزات مختلفة من النيكل ، تراوحت بين ٢٥ - ٤٠٠ جزء في المليون . وتلي ذلك زراعة البذور في تربة رملية ، وذلك لدراسة تأثير النيكل الممتص على نسبة الإنبات في الوزن الجاف للنبات ، نسبة الكربوهيدرات ومحتوى العناصر المعدنية (الحديد ، المنجنيز والزنك) . وجد أن نسبة الإنبات قد انخفضت بدرجة ملحوظة في الفول البلدي خاصة مع التركيزات العالية من النيكل ، في حين أن الذرة لم تتأثر . كما أن التركيزات المنخفضة من النيكل قد أدت إلى زيادة إنتاج نبات الذرة من المادة الجافة ، وتخليق الكربوهيدرات وامتصاص العناصر ، وذلك بالمقارنة بالفول البلدي ، في حين أدت التركيزات العالية من النيكل إلى تدهور نمو النبات وقلة محتواه من الكربوهيدرات والعناصر المعدنية . إلا أن النتائج كانت أكثر وضوحًا في الفول البلدي عنه في الذرة .