J.K.A.U.: Sci., vol. 4, pp. 15-21 (1412 A.H./1992 A.D.

The Effect of Nickel on Plants. III. The Effect of Foliar Nickel on Yield and Elemental Content of Some Crops

M.H. Rabie, E.A. Abdel Latif, K.G. Asy and M.E. Eleiwa*
Soil and Water Research Institute, Agricultural Research Centre, Cairo, Egypt; and
**Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia*

Abstract. In a greenhouse, wheat, faba beans and sorghum were grown on loamy soil treated with different amounts of foliar nickel sulphate. Nickel levels of 15,30,45, and 60 ppm led to an obvious accumulation of nickel in plants and to a slight increase in the dry matter production. With regard to the heavy metals absorption in plants, the cations were accumulated in the order Fe > Mn > Zn > Ni. But faba beans (Giza 2), absorbed higher amounts of those elements than wheat (Sakha 69) and sorghum (Giza 15). Significant amounts of nickel were found in wheat grains, by increasing its concentration in shoots for Fe and Zn the opposite was true, while in Mn it was not true.

Introduction

In addition to other heavy metals, which may be found in sewage sludges or industrial wastes, *i.e.* Zn, Cu, Cr, nickel was the element most likely to damage crops with some reinforcement in effect from the others[1]. Nickel phytotoxicity varies with the concentration of Ni in soil solution as well as with the plant species[2]. Stimulatory effect of nickel at low concentration have also been reported in some species, but as soon as the concentration increases beyond a critical limit, which may vary from species to another species, the adversed effects on plants become apparent[3]. Nickel when applied in excess is believed to interfere with iron uptake and metabolism causing chlorosis and necrosis[4-6]. Information on the beneficial effect of Ni, as seed soaking or soil addition, on plants were given in previous publications[5,7-9]. Although, Frieden[9] did not describe nickel as an essential micronutrient, but he could not note the strong possibility that it was, while Keeney[10] went further and described it as essential in trace quantities for crop plant growth. Dixon *et al.*[11] noted evidence which strongly indicated that urease was a nickel metalloenzyme. Lepp[12] reported that new members, *e.g.* nickel, have recently been added to the essential metals group.

The present work was conducted to study the effect of foliar nickel on yield and elemental content of faba beans, wheat and sorghum plants.

Material and Methods

Three pot experiments were carried out at the Agricultural Research Centre at Giza using three plant species; faba beans (Giza 2), wheat (Sakha 69) and sorghum (Giza 15), during the two successive years 1987 and 1988.

The important characteristics of used oil are shown in Table 1 . Mechanical analysis, total soluble salts (TSS) and pH value were determined according to the methods described by Piper[13]. Calcium carbonate content was determined volumetrically using Collin's calcimeter apparatus[14]. The chemical available heavy metals were determined according to Lindsay and Norvell[15].

TABLE 1. Characteristics of soil.

Sand %	Silt	Clay	Texture	$CaCO_3$ %	TSS %	pH (1:2.5)	Total (Ni) (ppm)	Chemical available elements (ppm)			
								Ni	Fe	Mn	Zn
...	...	30.5	Loamy	3.6	0.25	8.0	55.7	0.7	7.0	10.0	3.8

Four faba bean plants, ten wheat plants and six sorghum plants were grown in each pot for 6 weeks with replicates in the 1*st*, 2*nd* 3*rd* experiments, respectively. In the 2*nd* experiment, five plants of wheat in each pot were left for grain production. Through the growing seasons, 5, 2 and 2 g/pot of urea, superphosphate and potassium sulphate, respectively, were added to sorghum and wheat, while 0.5 g/pot of urea, 8 g/pot of superphosphate and 2 g/pot of potassium sulphate were used for faba beans. After 25 days from planting, nickel, at the rates of 0, 15, 30, 45 and 60 ppm, was applied as foliar spray.

Fifty days old plants were harvested using stainless steel scissors 1 cm above the soil level and dried at 70°C for 24 hours, and the dry matters were recorded. Harvested wheat plants were separated into straw and grains and their fresh weight were determined. The grains of each pot were air dried, ground and stored in clean jar for analysis. The plant material was digested by diacid mixture of the HNO_3 and $HClO_4$ (2:1). Analysis for Ni, Fe, Mn and Zn were performed with atomic absorption spectrophotometer, Pirken Elmer 2830.

Results and Discussion

Data in Table 2 shows that insignificant increase in dry matter yield was obtained in each crop when nickel concentration was increased up to 60 ppm. Similar results were obtained by Abdel Latif *et al.*[5] using sorghum. On the other hand, Eleiwa and Naguib[7] found that soil addition of 10^{-7}, 10^{-6}, 10^{-5} and 10^{-4} M of Ni reduced fresh and dry weight of soybean plants. Furthermore, Dobrolyubskii[16] concluded that tomato and corn plants showed an increase of water, ascorbic acid and enzymes in leaves, and also of photosynthesis and of carbohydrate metabolism when seeds were moistened with Ni solution before sowing.

TABLE 2. Effect of foliar nickel on dry matter yield and elemental content of the crops.

Foliar Ni (ppm)	Dry wt. mg/plant	Heavy metals (ppm in dry matter)			
		Fe	Mn	Zn	Ni
		Faba beans			
0	2.50	1806.0	226.7	166.7	6.7
15	2.50	2413.1	222.3	206.7	8.7
30	2.53	2580.3	216.7	186.6	10.3
45	2.60	1920.2	206.7	166.7	15.3
60	2.66	1827.6	193.3	153.0	20.8
L.S.D. (0.05)	N.S.	N.S.	N.S.	N.S.	0.86
		Wheat			
0	3.20	637.3	190.0	153.5	6.3
15	3.23	703.1	190.0	153.3	8.2
30	3.34	980.2	153.3	150.0	9.7
45	3.63	830.6	153.3	146.7	14.7
60	3.93	783.5	150.0	140.0	20.0
L.S.D. (0.05)	N.S.	22.5	9.8	N.S.	1.60
		Sorghum			
0	5.18	217.0	59.3	52.7	3.5
15	5.18	217.0	58.7	46.7	6.4
30	5.51	242.1	54.7	42.0	8.4
45	5.68	233.3	48.3	39.7	15.1
60	5.81	225.4	47.0	37.3	20.8
L.S.D. (0.05)	N.S.	N.S.	N.S.	N.S.	4.64

Nickel concentration in shoots of all crops was increased with increasing application rate of nickel. Addition of 60 ppm nickel increased Ni content in plants to about 20 ppm. These data coincided with those obtained by Khalid and Tinsely[17], and Rabie[6].

The order in which the ability of the crops under study absorbed the aforementioned heavy metals according to their content was: faba beans (Giza 2) > wheat (Sakha 69) > sorghum (Giza 15). Also, the order of the accumulation of these heavy metals in plant was Fe > Mn > Zn > Ni.

These data clearly show that the legume plant absorbed higher amounts of the essential heavy metals, than the cereals. But both absorbed parallel amounts of nickel, especially at the last treatments 45 or 60 ppm foliar nickel. These finding may be due to a specific vital mechanism in each of the aforementioned species which responded to nickel application with a restriction in nickel accumulation. Regarding plant adaptation to nickel toxicity, Abdel Latif *et al.*[5] found that most of nickel taken by roots was not easily transported to the tops of sorghum.

Concerning, the interrelationship between nickel and other essential metals in both legume and cereal, Fe, and Ni content in shoots increased and that of Mn and Zn decreased with increasing the levels of Ni application. These results are in agreement with those obtained by Eleiwa and Naguib[7], and Rabie *et al.*[8]. The pattern of Fe content is different, being highest at the middle level and reducing on both sides which showed that the increase of Ni content in shoots is proportional to the reduction in Fe content. These results may be due to the disturbed effect of pattern of nutrient uptake resulting in reduced uptake of some nutrients and increased supply of others. Several investigators, *e.g.* Kock[18], Rabie[6] and Abdel Latif *et al.*[5], reported that Ni when supplied in excess is believed to interfer with Fe uptake and metabolism causing Fe deficiency. Data also show that the Zn and Mn contents were depressed due to Ni application at all levels, showing that these elements are synergistic.

Mizuno[2] introduced the Fe/Ni ratio as a good parameter for Ni-phytotoxicty. He reported that there was a decrease in the crop yield when this ratio was less than 5, although symptoms of necrosis and chlorosis are not always developed. While, Crooke *et al.*[19] used the Ni/Fe ratio in plant and he reported that this ratio of more than 1 associated with the toxic effect of Ni. According to the former parameters, the Fe/Ni ratio is more than 5, and the Ni/Fe ratio is less than 1 in all crops under study interpreting their healthy growth during the time of experiments.

Data in Table 3 show that insignificant increase in both straw and grain yield was obtained when Ni was applied in various levels, especially at 60 ppm. Rouch and Brechley[20] reported a significant yield response to spray application of Ni on field crops of wheat, potatoes, and beans.

Concentration of 30 ppm Ni significantly developed grains. It can be noticed that the former decreasing pattern of Mn absorption in wheat shoots (Table 2), being the same in grains. Moreover, a significant gradual increase in Ni content of wheat grains parallel with that of shoots has been observed.

TABLE 3. Effect of foliar nickel on yield components and contents of heavy metals in grains.

Foliar Ni (ppm)	Straw (g)/ plant	Grain (g)/ plant	Heavy metals content in grain (ppm)			
			Fe	Mn	Zn	Ni
0	3.96	3.38	67.8	25.5	50.0	2.5
15	4.10	3.44	77.5	25.0	51.5	2.9
30	4.14	3.66	89.2	22.5	53.9	4.6
45	4.36	3.78	63.8	20.0	38.8	5.0
60	4.48	4.26	58.3	20.0	37.6	5.0
Mean	4.20	3.70	71.32	22.60	46.18	4.00
L.S.D. (0.05)	N.S.	N.S.	4.2	N.S.	6.93	0.32

Obvious accumulation of Ni in wheat grains, equal to two-fold of its content in the check, was found at 45 or 60 ppm foliar nickel. Halstend *et al.*[21] found a decrease in growth of oats when the nickel content of the grains exceeded 60 ppm and of the straw 28 ppm.

Data presented in Table 4 show that Ni correlates positively with grain yield, while Mn, Fe, and Zn have shown the reverse. Ni has shown negative correlation with Fe as well as with Mn and Zn. Strong positive correlation coefficients were existed between Mn and both Fe and Zn as between Fe and Zn.

TABLE 4. Correlation coefficient of wheat grain yield and the elemental content (ppm).

	Yield	Ni	Mn	Fe
Ni	0.60			
Mn	– 0.86	– 0.97		
Fe	– 0.84	– 0.86	0.96	
Zn	– 0.58	– 0.78	0.91	0.98

References

[1] **Vergnano, O.** and **Hunter, J.G.**, Nickel and cobalt toxicities in oat plants, *Ann. Botany* **17:** 317-328 (1952).

[2] **Mizuno, N.**, Interaction between iron, nickel, and copper in various plants species, *Nature* **912:** 1271-1272 (1968).

[3] **Brechley, W.E.**, *Minor Elements and Plant Growth, Biol. Rev. Cambridge Phil. Soc.*, 18, The Industrial Chemical Section Dev. and Res. Dept., The International Ni Co. Inc., 67 Wall Street, N.Y.S., N.Y., 159-171 (1943) (*c.f.* reference [5] Abdel Latif *et al.*)

[4] **Crooke, W.M.**, Further aspects of the relationship between nickel toxicity and iron supply, *Ann. Appl. Biol.* **43:** 465-476 (1958).

[5] **Abdel Latif, E.A., Rabie, M.H., Aboshelbaya, M.A.A.** and **Nofal, M.A.**, The effect of nickel on plants (I) Effect of seed soaking in nickel sulphate solution on the growth and chemical composition of sorghum, *Minia J. Agric. Res. Dev.* 10, **7:** 33-46 (1988).

[6] **Rabie, M.H.**, *Studies on Some Heavy Metals in Soils of ARE.* Ph.D., Thesis, Fac. of Agric., Ain Sham Univ. (1984).

[7] **Eleiwa, M.E.** and **Naguib, M.I.**, Response of soybean leaves to soil application of nickel, strontium or vanadium, *Egypt. J. Bot.* **29/30,** (1-3): 167-180 (1987).

[8] **Rabie, M.H., Abdel Latif, E.A., Nofal, M.A.** and **Asy, K.G.**, The effect of nickel on plants: (II) The effect of Ni on yield and elemental composition of wheat and clover. *Agric. Res. Rev.* (1988).

[9] **Frieden, E.**, The chemical elements of life, *Sci. Am.* **227:** 10-17 (1972).

[10] **Keeney, D.R.**, *Trace elements in agriculture,* International Report., Dept. of Soil Science, Univ. of Wisconsin, Madison, USA (1975).

[11] **Dixon, N.E., Gazzola, C., Blakeley, R.L.** and **Zerner, B.**, Jack bean urease (EC. 3.5.1.5) a metalloenzyme. A simple biological role for nickel, *J. Am. Chem. Soc.* **97:** 4131-4132 (1975).

[12] **Lepp, N.W.**, *Effect of Heavy Metal Pollution on Plants, Applied Science Publishers,* London and New Jersey (1981).

[13] **Piper, R.T.**, *Soil and Plant Analysis,* Univ. of Adelaide Press, Australia (1950).

[14] **Jackson, M.L.**, *Soil chemical analysis,* Constable & Co. Ltd., London (1958).

[15] **Lindsay, W.I.** and **Norvell, W.A.**, Development of DTPA soil test for Zn, Fe, Mn, and Cu, *Soil Sci. Soc. Amer. J.* **42:** 421-428 (1978).

[16] **Dobrolyubskii, O.I.**, Presowing treatment of seeds with trace elements, *Priroda* **48** (2): 95-97 (1958).

[17] **Khalid, B.Y.** and **Tinsley, J.**, Some effect of nickel toxicity on ryegrass, *Plant & Soil* **55:** 139-142 (1980).

[18] **Kock, P.C. de,** Heavy metal toxicity and iron chlorosis, *Ann. Bot.* **20:** 133-141 (1956).
[19] **Crooke, W.M., Hunter, J.G. and Vergnano, O.,** The relationships between nickel toxicity and iron supply, *Ann. Appl. Biol.* **41:** 311-324 (1954).
[20] **Rouch, W.A.** and **Brechley, C.,** Nickel and multiple trace elements deficiencies in agricultural crops, *Nature* **157:** 696 (1946).
[21] **Halstend, R.K., Finn, B.J.** and **Maclean, A.J.,** Extractability of nickel added to soils and its concentration in plants, *Can. J. Soil Sci.* **49:** 335-342 (1969).

أثـــر النيكـل على النبـاتـات : (٣) - تأثــير إضافــة النيكل رشًا على المحصول والمحتوى العنصري لبعض المحاصيل الحقليـــة

محمد حسن ربيع ، السيد أحمد عبد اللطيف ، كامل جبر عاصي و منى محمد الحسيني عليوة*
مركز البحوث الزراعية ، معهد بحوث الأراضي والمياه ، القاهرة ، مصر ؛
و *كلية العلوم ، جامعة الملك عبد العزيز ، جـــدة ، المملكة العربية السعودية

المستخلص . أجـريت ٤ تجارب أصص باستخـدام تربة طميية من محافظة الجيزة على نباتات الفول البلدي والقمح والذرة الرفيعة بغرض دراسة تأثير إضافة كبريتات النيكل رشًا على النمو الخضري والمحتوى العنصري للنباتات المذكورة . أحدثت التركيزات المستخدمة من النيكل زيادة غير معنوية في الوزن الجاف مع تراكم واضح من النيكل في النباتات . ولقد أمكن ترتيب مدى التراكم للعناصر تحت الدراسة في النباتات السابقة الذكر كالتالي :

حديد > منجنيز > زنك > نيكل

أما بالنسبة للنباتات فكان الترتيب هو :

فول بلدي > قمح > ذرة رفيعة

لوحظ تراكم كميات معنـوية من النيكـل في حبـوب القمح عند زيادتها في المجموع الخضري ، في حين تناقص محتوى الحبوب من الحديد والمنجنيز والزنك . وجدير بالذكر أن النباتات المذكورة لم تظهر عليها أية أعراض سُمية أو نقص عنصري ، وكان نموها جيدًا خلال فترة النمو .