International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p:511-518

Effect of Cobalt on Growth and Cobalt Uptake of Barely In Relation to Cobalt Availability in Alkaline Soils

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ABSTRACT

A short term Neubauer experiment was conducted to evaluate the effect of cobalt on the growth as well as cobalt uptake of barely (Giza 126 variety) grown in three alkaline soils from the north west coast of Egypt in relation to AAAA-EDTA (Acetic Acid Ammonium Acetate-EDTA) extractable cobalt in the tested soils of the uncropped treatments. Treatments of five levels of cobalt (0, 5, 10, 20, 40, 80, and 100 mg/kg soil) were superimposed on the tested soils. The data indicated that the available cobalt concentration increased with increasing cobalt application rate. The concentration of cobalt extracted with AAAA-EDTA increased polynomialy in response to cobalt application for the three studied soils. The data showed also, that the effect of cobalt application on the growth of barely plants was significant on the clay soil (Soil A) and insignificant on the clay loam and sandy loam soils (Soils B and C). The higher dry matter yields were obtained with the application of cobalt to the soils at the rate of 20 mg Co/Kg soil. The tolerance index (Ti) for the addition of 5 to 80 mg Co/Kg soil (>1) shows a favourable effect for the growth of barley. Also, the tolerance index was varied with the soil characteristics. Cobalt concentration or uptake by barley was increased significantly with cobalt application and this was also evidenced by the increase in AAAA- EDTA extractable cobalt from the tested soils. The average uptake values of cobalt followed the sequence order: soil C (sandy loam) >soil B (clay loam)> soil A (clay). Also percentage utilization of added cobalt was highest in soil C followed by soil B and soil A. In conclusion the application of cobalt in a low level improved growth of barely and may be applied to the soil at the recommended rate in term of cobalt sulphate.

Keywords: Cobalt, alkaline soils, barely, growth, availability, uptake and tolerance index.

INTRODUCTION

The essentiality of cobalt for higher plants has not been definitely established, even though cobalt is required by Rhizobia for nitrogen fixation and indirectly by leguminous and other plants (Ahmed and Evans, 1964; Riley and Dillwarth, 1985; Jana *et al.*, 1994). It is clear, however, that low concentrations of cobalt can have a favourable effect on plant growth of non leguminous ctrops (Lipskaya *et al.*, 1978; Lipskaya, 1980; Vyrodova, 1981; Yagodin and Sablina, 1981; Hussein, 1984; El-Kobbia and Osman, 1987; Toma and Lisnik, 1988; Yagodin and Stupakova, 1988; Yagodin *et al.*, 1990; Liu *et al.*, 1995 and Walser *et al.*, 1996).

According to some reports, cobalt is associated with auxin metabolism and promotes elongation of cell envelopes, activates dehydrogenises, nitrate reductase, increases the content of chlorophyll, total hematin and vitamin E genetically associated with chlorophyll (Yagodin, 1982). Application of cobalt is very important to enhance the nutritive value of farm products as a result of its increased content in crops. It has been demonstrated that , when the cobalt content in feeds is less than 0.07 mg/Kg of dry hay, animals suffer from cobalt deficiency (McDowell *et al.*, 1983) Therefore, cobalt containing fertilizers should be applied to pastures in areas of cobalt deficiency to obtain high quality animal feeds and foodstuffs.

The upper critical level of an element is the lowest tissue concentration at which it has toixic effects (Macnicol and Beckett, 1985). Anderson *et al.*, (1973) mentioned that with cobalt content above 6 ppm in plant, toxicity appeared. Cobalt deficiency occurs in highly leached sandy soils derived from acid igneous rocks or in highly calcareous soils. In Egypt, the studies of cobalt in soil and plant have received practically little attention till now. The aim of this work was to study the response of barley to applied cobalt in a short-term experiment in relation to cobalt availability in the alkaline soils.

MATERIALS and METHODS

Soil Samples:

Three samples of surface soil were collected from the Northern western coast of Egypt. Two selection criteria were followed in choosing the soils, i.e. the organic carbon and $CaCO_3$ contents in the 0-30 cm layer. Soil samples were air dried, ground, and passed through a 2 mm sieve. Some of the chemical and physical characteristics of these soils are presented in Table 1. Total cobalt was determined by atomic absorption spectrometry after digestion the soil samples using perchloric and nitric acids mixture according to Hesse(1971). Also, available cobalt in the tested soils was measured by extracting the soils with acetic acid-ammonium acetate-EDTA mixture (AAAA-EDTA) according to Sillanpaa and Jansson (1992) and the extractable cobalt were measured using the atomic absorption spectrophotometer. The other physical and chemical characterizations were determined in accordance with the procedure described in Black *et al.*, (1965).

Response of Barley:

A Neubauer experiment was carried out to study the effect of adding cobalt in the form of $CoSO_4$ at the rates 0, 5, 10, 20, 40, 80 and 100 mg Co/kg soil using the selected three soils on relative cobalt availability to barley plants (Giza 126 variety). 100 g air-dry soil samples were thoroughly mixed with 50 g acid-washed sand and placed in polyethylene containers 9.5 cm in diameter and 4 cm in height. The soil-sand mixtures were covered with 50 g acid-washed sand. Hundred barley seeds were uniformly planted on the sand surface, then covered by another 50 g sand layer. Barley seeds were soaked in distilled water for three hours before planting. Successful seed germination exceeded 90% and moisture losses were replenished daily. All treatments were conducted in duplicate, in addition to a blank treatment of 100 seeds in acid-washed sand. After 21 days, whole plants (shoots and roots) were harvested, washed and dried at 65°C for 48 hours. The plants were weighted, grounded and ashed according to Jackson (1973) for cobalt measurement. The same treatments were similarly prepared, but left uncropped for comparison. The soil sand mixture of the uncropped treatments at the end of the Neubauer experiment were air-dried, sieved through 1 mm screen for separating soil from sand and soil available cobalt were determined as previously described. The cobalt in the different soils was measured using the atomic absorbtion spectrophotometer.

Data Analysis :

Plant weight and cobalt concentration data were evaluated by analysis of variance and by the least significant difference (LSD) mean separation procedures at the 0.05 level of significance (SAS Insituate., 1994). Non linear regression was used to develop predictive equations relating available cobalt concentration responses to cobalt application rates. Regression analysis also was employed to determine the relationships between cobalt application rates to soil and cobalt concentrations and uptake in plant tissues.

RESULTS AND DISCUSSION

Available cobalt:

The effect of cobalt application on the available cobalt concentration in the tested soils of the uncropped treatments are shown in Table 2. The data indicated that the available cobalt concentration increased with increasing cobalt application rate. Relatively differences in the available cobalt between the tested soils at the different rates of cobalt application were observed. Soil C gave the largest amounts of available cobalt under the experimental conditions. The variation in the available cobalt content between the tested soils may be due to the reactions of the extractant with the soil components and the ability of the extractant to dissolve the cobalt in soil. The polynomial quadratic model was used to describe the relationship between cobalt application rates and extractable cobalt (Fig. 1). The concentration of cobalt extracted with AAAA-EDTA increased polynomialy in response to cobalt application for the three studied soils. The ability of extractant to remove cobalt from soils was in the following order : Soil C > Soil B> Soil A. The highest amounts of extractable cobalt from Soil C soil may be due to its lowest content from organic matter and clay fraction (Table 1). Bloomfield (1981) considered that the soil rich in organic matter are known to have allow cobalt availability.

Barley Response:

The data in Table 3 showed that barley dry matter yields increased significantly with cobalt application up to certain limit (20 mg Co/kg soil) for soil A and insignificantly for soils B and C. However higher cobalt applications reduced the yield to a values nearly equal to yield of the untreated plants with cobalt. The maximum dry weight was obtained at 20 mg Co/kg soil and accounts for 108.8 , 123.2 and 107.8% as compared with control for soils A, B and C respectively. The dry weight of barley plants were decreased at the higher rates of cobalt application without visual chlorotic symptoms on barley plants. The tolerance index (T_i) as defined by Bradshaw (1968) was calculated for the addition of 5, 10, 20, 40, 80 and 100 mg Co/kg soil (Table 3). The toxicity of cobalt under the present soil conditions depends not only on the absolute concentrations of cobalt in soil but also, on several other factors such as pH, fixation and /or complexing of cobalt by organic matter, and relative concentrations of other nutrients. The values of T_i that are more than one, shows a favorable effect for the growth of barley grown in the three soils. For soils A and C the cobalt application at 100 mg Co/kg (Table 3) showed a slight phytotoxic effect (T_i = < 1). The slight increases in growth of barley with cobalt application may be due to DNA synthesis and cell division (Yagodin, 1982). Similar results were obtained by Atta Aly *et al.* (1991) using nutrient culture.

Plant Uptake:

Table 4 shows that the concentration and uptake of cobalt were increased significantly with cobalt application up to 100 mg Co/kg soil. A highly positive significant correlations between cobalt application and cobalt concentration or uptake for the barley plants grown in the tested soils were observed (Table 5). The uptake values of cobalt varied widely among soils. The barely plants grown in the soil C (sandy loam) had a higher assimilative capacity or uptake of cobalt than the other two soils. The increases in cobalt concentration and uptake with increasing cobalt application were also evidenced by the increase in the AAAA-EDTA extractable cobalt from these soils (Table 2 and Fig. 1). In general the average uptake values of cobalt followed the sequence order: soil C (sandy loam) > soil B (clay loam) > soil A (clay). Corresponding to the data in Table 4, the percentage utilization of added cobalt was highest also in soil C, followed by soil B and soil A (Fig.2).

Both essential and non-essential elements exhibit an upper critical level above which yields are reduced because of toxic effects (Burton and Morgan, 1983). Considering cobalt element as non essential element to barley plants, the upper critical level range of cobalt will be 17.24 to 27.30 mg/Kg dry matter of barley for all the tested soils and the corresponding AAAA-EDTA cobalt in same soils were 10.56 to 14.56 mg Co/Kg soil. Davis *et al.*(1978) reported that 6 mg Co/Kg dry matter of barley seedlings produced toxicity symptoms. However, commonly reported critical cobalt levels in plants ranged from 30 to 40 mg Co/Kg dry matter (Macnicol and Beckett, 1985).

In conclusion the application of cobalt in a low level improved growth of barely and may be applied to the soil at the recommended rate in term of cobalt sulphate. Also, application of cobalt is very important to enhance the nutritive value of farm products as a result of its increased content in crops. The critical level derived in this study are no more precise, but we present it as the basis for preliminary assessments of cobalt in the tested plants to obtain high quality animal feeds and foodstuffs. Thus we need to develop more exact tests through more exploratory experiments on several fodder plants to drive more precise values for cobalt.

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Table (1). Some physical and chemical characteristics of the tested soils

Characteristics	Units	Soil A	Soil B	Soil C
Sand	g kg $^{-1}$	197.2	357.2	813.6
Clay	g kg $^{-1}$	467.2	308.5	130.1
Silt Texture	g kg $^{-1}$	335.6	334.3	56.3
		Clay	Clay loam	Sandy loam
$CaCO_3$	g kg $^{-1}$	95.0	206.0	333.0
Organic matter	g kg $^{-1}$	19.0	13.0	6.0
CEC,	cmol kg $^{-1}$	44.3	33.9	5.3
pH (1 : 1)		7.5	7.3	8.2
EC (1 : 2.5)	dS m $^{-1}$	1.6	1.5	0.3
Total cobalt	g kg $^{-1}$	29.0	18.2	21.1
Available cobalt,	g kg $^{-1}$	4.8	4.8	4.3

Table (2). The effect of cobalt application on the AAAA-EDTA extractable cobalt in soils without cropping.

Cobalt rate, mg/Kg soil	Soil A	Soil B	Soil C
0	4.10	4.70	4.18
5	6.30	6.85	6.84
10	8.18	7.20	8.74
20	10.56	13.87	14.56
40	18.00	20.34	25.94
80	39.20	45.50	47.40
100	48.00	63.00	73.02
L.S.D.$_{0.05}$	3.27	2.54	2.60

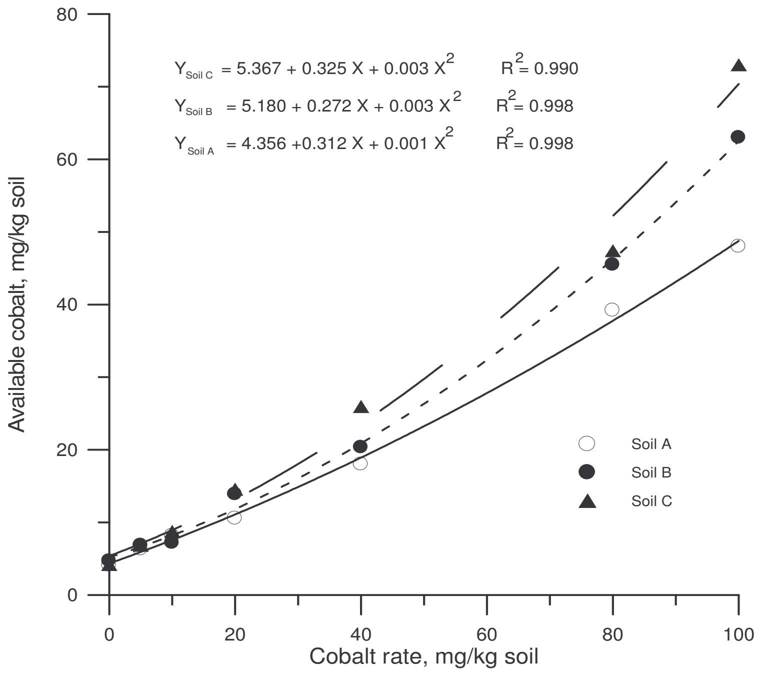

Fig. 1: Effects of cobalt application rates on the levels of AAAA-EDTA extractable cobalt in the three studied soils

Table (3). Growth and tolerance index (T_i) of barley plants as affected by cobalt application.

Applied Co mg kg^{-1}soil	Soil A		Soil B		Soil C	
	Dry matter yield g/pot	Tolerance index (T_i)	Dry matter yield g/pot	Tolerance index (T_i)	Dry matter yield g/pot	Tolerance index (T_i)
0	2.15	1.00	2.18	1.00	2.38	1.00
5	2.46	1.14	2.24	1.03	2.50	1.10
10	2.60	1.21	2.28	1.05	2.59	1.10
20	2.65	1.23	2.35	1.08	2.59	1.10
40	2.64	1.23	2.35	1.07	2.48	1.00
80	2.21	1.08	2.26	1.04	2.40	1.01
100	2.13	0.99	2.20	1.01	2.36	0.99
L.S.D$_{0.05}$	0.217	-	ns	-	ns	-

$$Ti = \frac{\text{Growth in enriched soil}}{\text{Growth in normal soil}}$$

Table (4). Cobalt concentrations and uptake of barley as affected by cobalt application to the three soils.

Applied Co mg kg^{-1}soil	Soil A		Soil B		Soil C	
	Conc. mg/kg D.M.	Plant uptake µg Co/pot	Conc. mg/kg D.M.	Plant uptake µg Co/pot	Conc. mg/kg D.M.	Plant uptake µg Co/pot
0	0.32	0.69	0.44	0.95	0.27	0.65
5	3.65	8.75	3.50	7.85	7.24	18.13
10	12.32	32.03	9.28	21.16	14.08	36.56
20	17.24	45.68	27.30	64.29	26.12	67.39
40	28.20	74.44	42.00	98.70	46.24	114.86
80	76.72	169.93	69.60	157.57	83.12	199.48
100	76.88	163.75	76.80	169.26	86.84	205.29
L.S.D$_{0.05}$	8.788	22.35	4.135	16.87	8.543	22.76

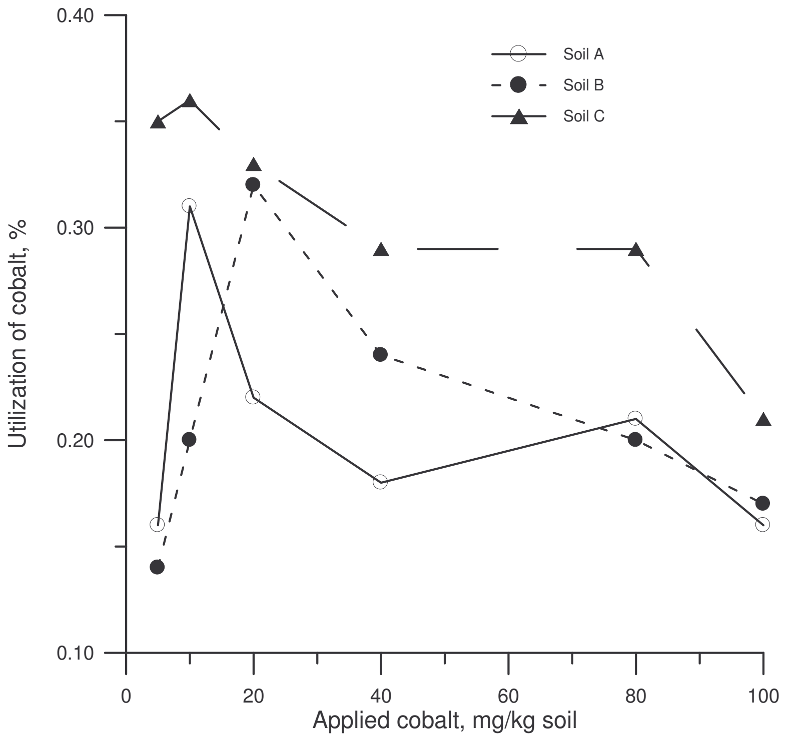

Fig.2 :Utilization percentages of added cobalt by plants in the three studied soils.

Table (5). Simple regression equation between applied cobalt (Y) and cobalt concentration in barley (X_1) or plant uptake (X_2).

Soil No.	Simple regression equation	r
A	$Y = 1.1807\ X_1 + 0.1214$	0.986^{**}
A	$Y = 0.5508\ X_2 - 2.5432$	0.982^{**}
B	$Y = 1.2355\ X_1 - 3.9769$	0.984^{**}
B	$Y = 0.5495\ X_2 - 4.7448$	0.978^{**}
C	$Y = 1.0921\ X_1 - 4.7448$	0.988^{**}
C	$Y = 0.4597\ X_2 - 5.7541$	0.985^{**}