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Growth and Productivity of Okra (*Abelmoschus esculentus* L.) as Affected by the Application of Cobalt Supplement

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ABSTRACT

Two field experiments were conducted to evaluate the effect of cobalt on Okra growth, pods yield quantity and quality. Okra seeds were sown in Research and production-National Research Centre, El-Nabaria site, Elbehera Governorate, Egypt. Seedlings were irrigated with cobalt sulphate once, with different cobalt levels: 0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 ppm under drip irrigation system during 2012 and 2013 seasons.
The obtained results are summarized in the following:-
-All cobalt rates significantly increase growth and yield parameters, mineral composition and chemical constituents of Okra pods comparison with control.
-Cobalt at 7.5 ppm has superior values.
-Cobalt levels till 7.5 ppm has a promotive effect on Okra growth, yield, nutritional status as well as chemical constituents.
-Increasing cobalt level above 7.5 ppm reduces the promotive effect.
-Increasing cobalt concentration in plant media resulted in a progressive depression effect of iron. Certain antagonistic relationships between the two elements (Fe and Co).

Key words: Okra, *Abelmoschus esculentus* ,Cobalt, pod yield quantity and quality

Introduction

In Egypt, okra considered a summer vegetable crop and cultivated for its edible green pods which can be used as fresh, canned, frozen, or dried food. Okra (*Abelmoschus esculentus* L.) belongs to the family, Malvaceae , and is grown as summer vegetable throughout the tropical and sub- tropical regions of the world (Charrier, 2010).

Okra is a powerhouse of valuable nutrients, nearly half of which is soluble fiber in the minerals and vitamins, which plays vital role in human diet and health. Okra has different uses as a food and a remedy in traditional, medicine since it proteins play a particularly important role in human nutrition. Okra seed oil is also rich source of linoleic acids polyunsaturated fatty acids essential for human nutrition. Okra has been a' perfect popular vegetable (Sami, 2013).

Cobalt is also required as a part of a bacterial enzyme complex. Given that these elements play important structural roles in the proteins, they are critical nutrients for the nitrogen-fixing bacteria. Cobalt is considered as a beneficial element for higher plant despite absence of evidence of its direct role in plant metabolism. Cobalt is an essential element for the synthesis of vitamin B12, which is required for human and animal nutrition (Smith, 1991).

Cobalt does not accumulate in human body as the other heavy metals. The daily cobalt requirements for human nutrition could reach 8 ppm depending on cobalt levels in the local supply of drinking water without health hazard, (Young, 1983). Chao-Zhou *et al.* (2005) found that cobalt increase cytoplasmic 0smotic pressure, leaf resistance to dehydration and decreased the wilting coefficient of potato plants. Plants treated with cobalt alleviated the reduction in polyamine contents and in the activities of antioxidative enzymes under osmotic stress (Tewari *et al.*, 2002). Nadia Gad (2005) stated that cobalt at 7.5 ppm had a significant promotive effect on tomato growth, yield and fruits quality such as total soluble solids, total soluble sugars, vitamin "C" as L-Ascorbic acid, titrable acidity and mineral composition compared with control and other cobalt levels.

Nadia Gad and Nagwa Hassan (2011) reported that cobalt addition in the growing media enhanced all parameters of sweet potato growth, yield quantity and quality compared with control plants. Cobalt at 10 ppm resulted the superior ones. Nadia Gad and Abd El-Moez (2011) stated that the addition of 6 ppm cobalt in Broccoli growing media gave the highest growth parameters, heads yield quantity and quality. Nadia Gad (2012) showed that the addition of 7.5 ppm cobalt had a significant synergistic effect on egg plants fruits quality such as the content of total proteins, total soluble solids, total carbohydrates and vitamin "C" as L-Ascorbic acid

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and the nutritional status. On the other hand, titrable (as citric acid) showed the negative response to all cobalt doses. Decreasing of titrable acidity improve the quality of eggplant fruits. Nadia Gad and Nagwa Hassan (2013) found that all cobalt concentrations significantly increased growth and yield parameters of sweet pepper compared with control plants. Cobalt at 5 ppm gave the greatest growth, yield quantity and quality. Attia *et al*. (2014) demonstrated that cobalt at 10 ppm gave a significant positive effect on the two onion cultivars growth, bulb yields quantity such as a bulb length, diameter and weights along with bulb quality such as nutritional status and essential oils content. Also, the percentage of both mitotic index and chromosomal aberrations increased with the dose reached its maximum value at 10 ppm cobalt. Cobalt at 7.5 ppm improve the germination of seeds for "Giza 6 Mohassan" while cobalt 10 ppm improve "Shandweel 1" seeds germination.

The aim of this study was to investigate the influence of cobalt supplementation on Okra growth and productivity.

Materials and Methods

Soil analysis: -

Physical and chemical properties of Nubaria soil samples were determined as well as particle size distributions and soil moisture were determined as described by Blackmore (1972). Soil PH, EC, cations and anions, organic matter, $CaCo_3$, total nitrogen and available P, K, Fe, Mn, Cu were determined according to Black *et al*. (1982). Determination of soluble, available and total cobalt was determined according to method described by Cottenie *et al*. (1982). Some physical and chemical properties of Nubaria soil sample are shown in Table (1).

Table 1. Some physical and chemical properties of El-Nobaria soil

Physical properties							
Particle size distribution %				Soil moisture constant %			
Sand	Silt	Clay	Soil texture	Saturation	FC	WP	AW
70.8	25.6	3.6	Sandy loam	32.0	19.2	6.1	13.1

Chemical properties											
				Soluble cations ($meq^{-1}L$)				Soluble anions ($meq^{-1}L$)			
pH 1:2.5	EC ($dS\ m^{-1}$)	CaCO3%	OM %	Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	CO_3	Cl^-	$SO_4^=$
8.49	1.74	3.4	0.20	0.8	0.5	1.6	1.80	0.3	0.0	1.9	0.5

Cobalt			Total	Available		Available micronutriments			
Ppm			mg 100 g^{-1} soil			Ppm			
Soluble	Available	Total	N	P	K	Fe	Mn	Zn	Cu
0.35	4.88	9.88	15.1	13.3	4.49	4.46	2.71	4.52	5.2

FC (Field capacity), WP (Welting point), AW (Available water).

Experimental works: -

A preliminary experiment was conducted at Wire house of National Research Centre, El-Bohooth Street, Dokki, Cairo, Egypt, to define cobalt concentrations range which gave growth and yield response of Okra plants. Two field experiments were carried out at the Research and production Station, National Research Centre- El-Nubaria site, Beheara Governorate, Delta-Egypt, during two successive seasons of 2012 and 2013, to evaluate the effect of different cobalt levels (0.0,2.5,5.0,7.5, 10 and 12.5 ppm) on growth and yield parameters, nutrients status and some chemical constituents of Okra pods.

Okra seeds "Balady" cultivar was sowing on 20 and 23 March of 2012 and 2013 seasons under drip irrigation system. Super phosphates at 100 Kg fed-1, 150 Kg fed-1 Ammonium sulphate were added during soil preparation before sowing. Potassium sulphate at 100 Kg fed^{-1} was adding during 30 days from sowing. Seedlings (at the third truly leaf) were irrigated with cobalt sulphate forms once, with the different cobalt concentrations (control, 2.5, 5.0, 7.5, 10 and 12.5 ppm cobalt). Each treatment was represent by 3 plots. Each plot area was 5x5 meter, consisting of five rows. Ten plants in each row (50 cm apart). All plants received natural agricultural practices whenever they needed.

Measurement of plant growth parameters: -

At full blooming stage i.e., 60 days from sowing, a representative sample of ten plants was taken from each plot. Some growth parameters such as plant high, number of branches and leaves per plant, shoot and root fresh weights as well as biomass of both shoots and roots per plant in the two seasons were recorded in according to FAO (1980).

Measurement of pods yield parameters: -

At harvest stage (after 90 days from sowing) the mature pods of Okra for each experimental plot were collected along the harvesting in the two seasons, some yield parameters such as pods number per plant, pods length, pods diameter, pods weight per plant and pods yield per feddan were recorded according to Gabal *et al* (1984).

Measurement pods nutritional status: -

Macronutrients (N, P and K) and micronutrients (Fe, Mn, Zn and Cu) along with cobalt content were determined according to Cottenie *et al*. (1982).

Measurement pods chemical constituents: -

Total proteins, total carbohydrates, total soluble solids, vitamin "C" and vitamin "A" were determined according to A.O.A.C. (1995).

Statistical analysis: -

The obtained data were statistically analyzed of variance procedure outlined by (SAS, 1996) computer program and means compared by LSD method according to Snedecor and Cachran (1980).

Results and Discussion

Vegetative growth:-

Data in Table (2) show that the addition of different cobalt levels (2.5, 5.0, 7.5, 10 and 12.5 ppm) to the growing media significantly increase Okra growth parameters for two seasons compared with control plants. Cobalt at 7.5 ppm gave the greatest values of all growth parameters such as plant height, number of branches and leaves per plant, shoot and root fresh weights as well as biomass of shoot and root of Okra. These results are in harmony with those obtained by Nadia Gad (2005a) who indicated that cobalt at 7.5 ppm had a positive effect due to several induced effects in hormonal synthesis (Auxins and Gibberllins contents) and metabolic activity resulted in maximum growth and yield of tomato, while the higher cobalt levels were found to increase the activity of some enzymes i.e. peroxidase and catalase in plant and hence increasing the catabolism rather than anabolism.

Table 2: Effect of cobalt on Okra growth parameters (mean of two seasons).

Cobalt treatments (ppm)	Plant height (cm)	Number/plant		Fresh weight/plant (g)		Dry weight/plant (g)	
		Branchs	Leaves	Shoot	Root	Shoot	Root
Control	77.2	3.66	16.83	188.8	36.52	42.32	9.89
2.5	82.0	4.03	18.52	219.6	39.06	48.76	10.49
5.0	84.7	4.65	21.08	237.5	43.13	53.45	11.66
7.5	87.5	5.06	24.27	251.7	45.42	55.86	12.46
10.0	85.8	4.89	22.72	247.3	43.60	55.56	11.78
12.5	82.6	4.58	20.43	239.4	42.52	53.22	11.49
LSD 5%	0.6	031	0.65	2.0	0.47	0.23	0.17

Yield characteristics:-

Data in Table (3) show that all cobalt doses significantly increased Okra pod yield parameters compared with control. Cobalt at 7.5 ppm gave superior values of Okra pods yield parameters such as pods number per plant, pods length, pods diameter, pods weight per plant along with pods yield per feddan. It is evident that cobalt at 7.5 ppm increased pods parameters per plant of: pods number 39.8%, pods length 32.6%, pods diameter 28.2%, pods weight 48.3%. Finally cobalt at 7.5 ppm increased pods yield (ton/feddan) 43.06%. Increasing cobalt concentrations in plant growing media more than 7.5 ppm, the promotive effect reduced.

These observations are in consistent with previous obtained by Boureto *et al*. (2001) who found that cobalt at 2.5 ppm in sand culture was found to be promotive effect for tomato growth and yield compared with control.Confirm these data Nadia Gad and Nagwa Hassan (2011) who stated that cobalt addition in plant media hence sweet pepper growth and yield quantity and quality compared with control.

Table 3: Effect of cobalt on Okra yield quantity and its physical characteristis (mean of two seasons).

Cobalt treatments (ppm)	Pods number per plant	Pods length (cm)	Pods diameter (cm)	Pods weight/plant (g)	Pods yield (ton/fed)
Control	69.98	3.12	1.74	225.91	1.498
2.5	72.13	3.36	1.87	240.76	1.589
5.0	85.24	3.82	1.98	283.87	1.941
7.5	99.81	4.14	2.23	335.11	2.143
10.0	88.34	4.12	2.22	323.10	2.820
12.5	85.78	3.97	2.16	309.39	2.665
LSD 5%	3.45	0.15	0.7	2.1	0.91

Nutritional status:-

Nitrogen, P and K content:

Data in Table (4) show that all cobalt levels significantly increased the content of N, P and K in Okra pods compared with control plants. The highest values of N, P and K content were obtained by 7.5 ppm cobalt. This means that increasing cobalt levels more than 7.5 ppm, the promotive effect reduced. Confirm these results Nadia Gad (2005a) stated that the addition of cobalt at 7.5 ppm had significantly syneregestic effect on the status of macronutrients (N, P and K) in tomato fruits and the higher concentrations of cobalt reduce the promotive effect. Also, Basu *et al*. (2006) indicated that cobalt significantly increased the status of N, P and K in groundnut plants compared with control.

Manganese, Zn and Cu Content:

Data in Table (4) show that all cobalt rates gave a significantly positive effect on the content of Mn, Zn and Cu in Okra pods compared with control. Increasing cobalt rate in plant growing media up to 12.5 ppm increased Mn, Zn and Cu content. These are agree with those obtained by Nadia Gad (2005) who found that, the concentrations of Mn, Zn and Cu in tomato fruits significantly increased with every increase in cobalt application in growing plant media.

Iron Content: -

Results in Table (4) indicate that increasing cobalt concentration (from 2.5 up to 12.5 ppm) in growing plant media resulted in a progressive depression effect on iron content of Okra pods grown for two seasons. This may be explained on the basis of the obtained results by Blaylock (1993); Nadia Gad and Nagwa Hassan (2013) who showed certain antagonistic relationships between the two elements (cobalt and iron), and revealed that the relative response of Fe to the control indicated continuous decrease of this element as a result of cobalt addition from 2.5 ppm till 12.5 ppm.

Cobalt content: -

Increasing cobalt levels in growing plant media from 2.5 ppm up to 12.5 ppm increased cobalt content in pods of Okra plants grown for two seasons compared with control plants (Table 4). These results clearly indicate that cobalt content goes along with the concentration of added cobalt. The obtained results are in good agreement with those obtained by Attia *et al*. (2014) who found that, increasing cobalt concentration in growing plant media increased cobalt content in onion bulbs. Young (1983) reported that the daily cobalt requirements for human nutrition could reach 8 ppm depending on cobalt levels in the local supply of drinking water without health hazard.

Table 4: Effect of cobalt on mineral composition of Okra (mean of two seasons).

Cobalt treatments	Macronutrients (%)			Micronutrients (ppm)				Cobalt
(ppm)	N	P	K	Mn	Zn	Cu	Fe	ppm
Control	0.632	0.122	0.861	39.6	31.2	26.3	141	0.67
2.5	0.673	0.127	0.887	42.0	34.1	28.5	137	0.88
5.0	0.722	0.133	0.924	46.7	36.5	30.8	132	1.36
7.5	0.785	0.159	0.978	42.3	38.9	33.6	125	2.14
10.0	0.785	0.152	0.974	50.6	40.0	35.4	119	3.47
12.5	0.787	0.147	0.968	52.2	42.3	37.2	116	5.63
LSD 5%	0.45	0.5	0.4	0.3	0.9	0.6	3.0	0.12

Chemical Constituents: -

Data in Table (5) resulted a significant favorable effect on studied chemical constituents compared with control. Cobalt at 7.5 ppm gave the greatest values of total proteins, total carbohydrates, total soluble solids, vitamin "C" and vitamin "A" in Okra pods. The relative calculated values as percentage from control. It is evident that cobalt at 7.5 ppm increased the content of: total proteins 29.2%, total carbohydrates 29.9%, total soluble solids 15.9%, vitamin "A" 10.07% and vitamin "C" 19.2% respectively (mean of two seasons).

These data are in harmony with those obtained by Nadia Gad (2005) who stated that soil application with cobalt increase total soluble solids, total soluble sugars and vitamin "C" in tomato plants compared with control. Confirm these results MorKova (2001) who showed that soil application of 0.7 Kg $CoSo_4$/hector before transplanting increased both total soluble solids and total soluble sugars compared with untreated tomato plants. Vitamin "A" is an important antioxidant and is essential to human growth, normal physiological functions, health of the skin as well as muscous membranes. Moreover, vitamin "C" is an antioxidant and is necessary to several metabolic processes and reduced gastric Cancer risk (Griffiths and Lunec, 2001).

Table 5: Effect of cobalt on Okra chemical constituents (mean of two seasons).

Cobalt treatments (ppm)	Total proteins	Total Carbohydrates	Total Soluble Solids	Vitamin "C"	Vitamin "A"
	%			Mg/100g fresh tissue	
Control	2.50	7.21	12.32	24.32	31.06
2.5	4.21	7.82	12.89	25.56	31.70
5.0	4.51	8.74	13.56	27.21	32.22
7.5	4.91	0.35	14.28	29.00	34.19
10.0	4.91	9.32	14.06	28.17	34.09
12.5	4.88	9.24	13.96	27.76	33.87
LSD 5%	0.30	0.11	0.22	0.55	0.63

Conclusion:

Cobalt is promising element in the newly reclaimed soils. It has a significant favorable effect on Okra growth, yield quantity and quality. From this study it could be suggest that cobalt is consider a beneficial element for higher plants. Therefore, considerable attention should be taken concerning applying this element (CO) as a fertilizer.

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