Australian Journal of Basic and Applied Sciences, 2(4): 949-955, 2008
ISSN 1991-8178

Response of Sweet Potato(*Ipomoea batatas* L) Plants to Different Levels of Cobalt

Nadia Gad and Hala Kandil

[1]Department of Plant Nutrition, National Research Centre, Cairo

Abstract: Two field experiments were conducted to evaluate the effect of cobalt on sweet potato growth, root yield and quality. Sweet potato root were sown in Nubaria Farm, National Research Centre. Cobalt was added in the form of cobalt sulphate in five concentrations i.e., 0.0, 5.0, 7.5, 10.0, 12.5 and 15.0 ppm. All the plants received natural agricultural practices during the growth period. All cobalt treatments significantly increased growth and yield parameters, nutrients status (except Fe content) and the chemical contents of sweet potato roots when compared with the control treatment. The obtained results indicated that the addition of 10 ppm cobalt had a significant promotive effect on the sweet potato growth and roots yield quality as starch, sugars caroteniods, TSS, L-Ascorbic acid and the contents of N, P, K, Mn, Zn and Cu as compared with other concentrations. Higher concentrations more than 10 ppm excerted adverse effect. Generally the obtained results showed that cobalt has a positive role on growth, root yield quality of sweet potato plants.

Key words: Sweet potato, Cobalt, Carotenoids, Starch, Sugars, Minerals content.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) can be grown with high yield, in artificial conditions using hydroponics. This is important, as the sweet potato is more nutritious and flavorful than white one and therefore can be grown in greater quantities. Sweet potato is an excellent source of complex carbohydrates, vitamins, minerals and beta-carotene. The starch in sweet potato converts to sugar easily and provides quick energy. However, sweet potato has an impressive list of nutrients, it is especially high in Anti-oxidants, Vitamin C, Beta carotene, Boron, Calcium, Copper, Cystine Fiber, Folic acid, Iodine, Iron, Magnesium, Manganese, Niacin, Phosphorus, Potassium, Protein, Sulfur, Tryptophan, Tyrosine, Vitamine B_6 And Zinc. It is actually superfood (Griffiths and Lunec, 2001).

Sweet potato is an important root crop grown all over the world and consumed either as vegetable, boiled, backed or often fermented into food and beverages. Selection of advanced sweet potato cultivars for human food will provide higher yield and improved nutrition (Vitamine A and Starch). It is generally the staple food and an important subsistances crop for humans (Muhammad and Yakub, 2005; Panda *et al.*, 2006).

In spite of the absence of evidence for direct role of cobalt in plant metabolism, it is considered to be a beneficial element for higher plants and is a kind of trace element and heavy metal found in soil (Hanson, *et al.*, 2001). Excess Co induces yield reduction and an inhibition in assimilates production in leaves and even inhibits the export of photoassimilates to roots and other sinks (Rauser and Samarakoon, 1980). Excess Co also, causes oxidative stresses and may result in phototoxicity to plant (Tewari *et al.*, 2002 and Chatterjee and Chatterjee, 2003). However, cobalt is unequivocally essential for leguminous crops as it is required for nitrogen fixation by bacteria in root nodules (Witte *et al.*, 2002) and it even has beneficial effect on some nonleguminous crops (Locke *et al.*, 2000).

Chao-Zhou *et al.*, (2005) found that cobalt increase cytoplasmic osmotic pressure, leaf resistance to dehydration and decreased the wilting coefficient of potato plants. Treatment with cobalt alleviated the reduction in polyamine contents and in the activities of anti-oxidative enzymes when osmotic stress (Tewari *et al.* 2002).

However, to the best of this knowledge, little research has been concluded in this field and physiological effects of Co in proper concentration on plants, remain unclear.

The present study was carried out to investigate the response of growth, yield nutrients status as well as some physiological parameters of sweet potato to different cobalt concentrations.

Corresponding Author: Nadia Gad, Department of Plant Nutrition, National Research Centre, Cairo

MATERIALS AND METHODS

Soil Analysis:

Physical and chemical properties of Nubaria soil, Research and Production Station, National Research Centre, are shown in Table (1). Particle size distribution along with soil moisture of the soil sample were determined as described by Blackmore (1972). Soil organic matter, $CaCO_3$, EC, pH, cations and anions, soluble and available micronutrients were determined according to Black *et al* (1982). Determination of soluble, available and total cobalt were run according to the method described by Cottenie *et al.* (1982).

Plant Material and Experimental Works:

Two field experiments were conducted during two successive seasons 2006 and 2007 at Nubaria farm, National Research Centre to evaluate the effect of different cobalt levels (0, 5.0, 7.5, 10.0, 12.5 and 15.0 ppm) on growth and yield parameters, nutrients status and some physiological parameters of sweet potato roots.

Sweet potato roots (*Ipomoea batatas* L) were sown on 10th April, 2006 and 2007 seasons under drip irrigation system with all agricultural managements required for production of seedlings as usually recommended. The seedlings (at the third truly leaf) were irrigated with cobalt sulphate once, with the different cobalt concentration (control, 5.0, 7.5, 10.0, 12.5 and 15.0 ppm). Each treatment was represented by 3 plots. Each plot area was 5 X 3 meter, consisting of three rows. Ten roots in each row (50 cm apart) were planted. All the plants received natural agricultural practices whenever they needed.

Measurement of Plant Growth and Yield Parameters:

After the growth period (155 days from planting), some growth and yield parameters were recorded i.e. plant height, No. of branches/plant, fresh and dry weight of herbs/plant, roots number/plant, root diameter and roots yield/ Fed were determined according to Gabal *et al.* (1984).

Measurement Tubers Quality:

Carotenoids %, starch %, mono sugar %, total soluble sugar %, total soluble solids % and L-Ascorbic acid (mg/100 g fresh tissue), were determined according to standard methods described by FAO (1980), A.O.A.C. (1980)

Table 1: Some physical and chemical properties of the used soil at Nubaria, Research and Production Station, National Research Centre.

Soil property	Particle size distribution %				Soil moisture constant %			
Physical	Sand	Silt	Clay	Texture	Saturation %	FC	WP	AW
	68.7	24.5	6.8	S L	32.0	19.2	6.1	13.1
	pH^a		EC^b dS/m		$CaCO_3$%		OM ^{c}%	
	7.8		0.18		7.07		0.16	
Chemical	Soluble cations (meq/l)				Soluble anions (meq/l)			
	Ca^{++}	Mg^{++}	K^+	Na^+	$CO_3^=$	HCO_3^-	Cl^-	SO4
	3.00	2.00	0.32	2.09	0.00	1.41	0.70	5.30
	Total	Available			Available micronutrients			
	N	P	K		Fe	Mn	ZN	Cu
	Mg/100 g soil				ppm			
	15.0	9.4	16.0		7.8	3.3	1.86	4.0
					Cobalt (ppm)			
					Soluble		Available	Total
					0.49		4.43	15.00

a: Soil pH was measured in 1:2.5 soil-water suspension, b: EC was measured as dSm^{-1} in soil paste,
S L: sandy loam c: organic matter.

as well as nutrients status after Cottenie *et al*., (1982). Total protein was calculated by multiplying total nitrogen by the factor of 6.24.

Statistical analyses of the obtained data for the two growing seasons were subjected to standard analysis of variance procedure. The values of LSD were calculated at 5% level according to the method of Snedcor and Cochran (1982).

RESULTS AND DISCUSSION

Growth and Yield Parameters:

Data presented in Table (2) show that addition of different cobalt levels (5.0, 7.5, 10.0, 12.5 and 15.0 ppm) to the growth media significantly increased plant height, number of branches /plant, fresh and dry weight of shoots, number of roots /plant and root yield/fed. of the sweet potato plants grown for two seasons as compared with control treatments. However, these increases did not reach the level of significant at 5% for No. of the branches /plant and roots number/plant by using cobalt level at 5 ppm as compared with control treatment. These results are true for the two growing seasons. The highest recorded results of the mentioned parameters of sweet potato (Table 2) were obtained in plants treated with 10 ppm, when cobalt addition increased more than 10 ppm (12.5 and 15.0 ppm) the promotive effect reduced all the growth and yield parameters of sweet potato as compared with the level of 10 ppm cobalt. These observations are consistent with previous reports obtained by Anter and Nadia Gad (2001) and Nadia Gad *et al* (2008), who stated that the lower doses of cobalt resulted in maximum growth and yield of plants as compared with the higher ones. They reported that responses associated with low cobalt levels may be attributed to catalase and peroxidase activities which were found to decrease with low levels of cobalt and increase with the higher ones. These enzymes are known to induce plant respiration, so superior resulting in successive consumption for products of photosynthesis and consequently reduced in plant growth.

Moreover, low cobalt levels being with positive effect due to several induced effects in hormonal synthesis and metabolic activity, while the higher cobalt levels were found to increase the activity of some enzymes such as peroxidase and catalase in plant and hence increasing the catabolism rather than the anabolism (Nadia Gad, 2005a).

Data presented in Table (2) show that addition of higher levels of cobalt (12.5 and 15.0 ppm) decreased all the growth and yield parameters of sweet potato grown for two seasons as compared with those obtained by using cobalt level of 10 ppm.

The obtained results of growth and yield of sweet potato (Table 2) are in agreement with those obtained by Laila Helmy and Nadia Gad (2002), Nadia Gad (2005 b), Basu *et al*., (2006) and Nadia Gad *et al*., (2008) who stated that growth and yield of parsley, tomato, groundnut and cucumber plants were significantly increased with lower levels of cobalt as compared with the higher ones.

Table 2: Effect of cobalt levels on growth and yield parameters of roots sweet potato grown for two seasons.

Cobalt levels	Plant height	No. branches	Fresh weight of shoots /plant	Dry weight of shoots /plant	Roots	Root diameter	Root yield
ppm	cm	/plant	gm		No./plant	cm	Ton/fed
First season							
Control	225.0	10.0	434.2	270.0	5.0	16.1	10.80
5.0	228.1	10.0	438.4	274.3	6.0	18.4	12.99
7.5	232.3	11.0	441.3	276.2	7.0	21.6	15.10
10.0	241.8	12.0	448.6	280.5	11.0	23.9	16.61
12.5	237.3	12.0	440.3	276.2	11.0	21.5	16.32
15.0	234.1	11.0	437.7	274.0	10.0	19.2	15.76
LSD at5%	2.45	0.81	3.11	3.60	1.8	1.14	3.76
Second season							
Control	231.0	11.0	448.1	277.0	5.0	17.1	10.90
5.0	235.2	11.0	453.1	281.3	6.0	19.3	11.49
7.5	238.4	12.0	455.6	283.4	8.0	22.5	15.44
10.0	247.1	13.0	460.8	286.8	11.0	24.4	16.82
12.5	271.4	13.0	456.1	283.2	12.0	21.5	16.55
15.0	237.6	12.0	452.7	281.4	11.0	18.6	15.95
LSD at5%	3.39	0.93	4.01	4.10	2.40	1.18	3.91

Table 3: Effect of cobalt levels on some chemical composition of sweet potato roots for two seasons.

Cobalt levels	Carotenoids	Protein	Starch	Mono sugar	Total soluble sugars	Total soluble solids	L-Ascorbic acid
ppm	%						mg/100 gm fresh tissue
First season							
Control	1.43	7.70	65.2	2.40	5.71	2.81	12.90
5.0	1.47	7.89	66.3	2.81	6.20	2.95	13.40
7.5	1.61	8.14	68.9	3.03	6.51	3.66	14.50
10.0	1.82	9.72	70.6	3.86	6.93	4.51	15.70
12.5	1.70	8.50	69.2	3.22	6.07	3.98	14.20
15.0	1.53	7.79	67.1	2.73	5.97	3.70	13.50
LSD at5%	0.04	0.14	1.01	0.20	0.19	0.10	0.20
Second season							
Control	1.51	8.10	68.0	2.60	6.00	2.80	13.40
5.0	1.59	8.33	69.5	3.10	6.41	2.99	13.90
7.5	1.75	8.91	70.3	3.47	6.72	3.72	14.80
10.0	1.98	10.21	72.5	4.10	7.07	4.66	16.00
12.5	1.82	9.06	70.0	3.70	6.40	4.01	15.30
15.0	1.66	8.40	68.9	2.81	6.21	3.89	14.20
LSD at5%	0.07	0.20	0.88	0.10	0.18	0.12	0.11

Chemical Analysis:

The amounts of (carotenoids %, protein %, starch %, mono-sugars %, total soluble sugars %, total soluble solids % and L-Ascorbic acid (mg/100 gm fresh tissue) in sweet potato roots as affected by different levels of cobalt are given in Table (3). Results indicate that all the mentioned parameters were significantly increased by the addition of cobalt levels (5.0, 7.5, 10.0, 12.5 and 15.0 ppm) as compared with those obtained by control treatments. In this concern, Nadia Gad (2005 b) revealed that soil application with cobalt increased total soluble solids, total sugars and Vitamine C in tomato plants as compared with untreated ones. The highest values of all the studied parameters are obtained by using the level of 10 ppm cobalt (Table 3).

The results in Table (3) show also the relative calculated values as percentage from control. It is evident that cobalt rate at 10 ppm increased the contents of: carotenoids 27-31 %, protein 26-27 %, starch 7-8 %, total soluble sugars 18-21 % and L-Ascorbic acid 19-21 %, respectively in the two seasons. While both monosugars and total soluble solids gave the high increase contents 58-61 % and 60-66 %, respectively in the two seasons. Carotenoids are now recognized as an important antioxidant and is essential to human growth, normal physiological functions, health of the skin as well as mucous membranes. Moreover, Vitamin C is an antioxidant and is necessary to several metabolic processes (Griffiths and Lunec, 2001).

Data also show that increasing the levels of added cobalt above 10 ppm (12.5 and 15.0 ppm) decreased all the mentioned parameters as compared with their corresponding values by using cobalt level of 10 ppm. However, these values were higher than those obtained by control treatments. These results are true for the two growing seasons. The obtained results show that cobalt has a positive role on the studied physiological parameters of sweet potato roots. These observations of the effect of cobalt addition on the studied parameters of the sweet potato roots are in good agreement with those obtained by Nadia Gad (2005 b and 2005 c) who indicated that cobalt level at 7.5 ppm had promotive effect for total soluble solids, total sugars and vitamin C content. The same author stated that increasing cobalt concentration over 7.5 ppm resulted in significant adverse effect and attributed this effect to the role of cobalt.

Data presented in Table (3) show that all the cobalt levels significantly increased L-Ascorbic acid (Vitamin C) in sweet potato roots as compared with control. L-Ascorbic acid is the major antioxidant in plant cells and is involved in photoprotection metal and xenobiotic detoxification, the cell cycle, cell wall growth and cell expansion. It acts as Co-enzyme in metabolic changes and involved in photosynthesis and respiration processes (Franceschi and Tarlyn, 2002). Moreover, a recent study indicates that leaf Ascorbic acid content can also modulate the expression of genes involved in plant defense and regulate genes that control developments through hormone signaling (Pastori *et al*, 2003). The increase in the studied criteria under the increasing effect of Ascorbic acid by cobalt addition might be indirect effect, as Ascorbic acid acts in many biochemical processes as mentioned before. In this concern, reported that application of ascorbic acid to tomato plants increased growth, yield and metabolic processes especially with energy Co-enzymes of tomato plants (Abdel Halim 1995). For human high Vitamin C dietary intake correlates with reduced gastric cancer risk (Griffiths and Lunec, 2001).

Table 4: Effect of cobalt levels on nutrients content in roots of sweet potato grown for two seasons.

Cobalt levels ppm	Macronutrients (%) N	P	K	Micronutrients (%) Fe	Mn	Zn	Cu	Cobalt ppm Roots	Shoots
First season									
Control	1.26	2.20	1.26	131.8	61.5	30.2	25.2	1.00	2.8
5.0	1.28	2.24	1.29	128.0	64.3	32.6	28.4	1.76	3.2
7.5	1.32	2.30	1.33	124.2	70.4	35.0	32.6	2.48	5.01
10.0	1.36	2.34	1.39	121.1	73.2	38.8	36.5	3.02	8.6
12.5	1.33	2.31	1.34	119.3	69.6	36.1	34.4	4.95	10.6
15.0	1.31	2.28	1.30	114.5	63.8	33.0	31.2	6.18	11.9
LSD at5%	0.05	0.07	0.04	2.7	1.9	1.2	2.1	0.68	0.6
Second season									
Control	1.20	2.25	1.37	126.0	64.0	32.0	27.4	1.30	2.9
5.0	1.23	2.30	1.41	122.1	69.1	34.5	30.3	1.84	3.4
7.5	1.26	2.36	1.46	118.2	72.0	37.6	35.3	2.62	5.04
10.0	1.30	2.42	1.51	115.3	76.3	40.3	38.0	3.41	8.8
12.5	1.27	2.40	1.45	112.1	70.6	37.9	36.1	4.25	10.9
15.0	1.26	2.37	1.42	109.4	66.7	34.5	34.6	6.36	12.2
LSD at5%	0.06	0.1	0.05	2.5	3.1	1.4	2.3	0.61	0.5

Nutritional Status in Plants:

Data in Table (4) clearly indicate the following:

Nitrogen, P and K Content:

Results presented in Table (4) show the effect of the different levels of cobalt (5.0, 7.5, 10.0 12.5 and 15.0 ppm) on macronutrients (N, P and K) in the roots of sweet potato grown for two seasons. Data revealed that all the cobalt levels significantly increased the content of N, P and K as compared with control treatments. Confirm these results Aziz Eman *et al*., (2007) who revealed that all the used levels of cobalt significantly increased the content of N, P and K in *Hibiscus sabdariffa* L. plant when compared with control treatment. The highest values of N, P and K content were obtained by using the cobalt level at 10 ppm, as compared with the other used levels. This means that increasing cobalt levels more than 10 ppm in plant medium (12.5 and 15.0 ppm) decreased the content of N, P and K in the roots of sweet potato as compared with those obtained by using 10 ppm. Confirm these results Nadia Gad (2006) stated that addition of low Co level of 7.5 ppm had significantly senrgestic effect on the status of macro nutrients (N, P and K) in fruit of tomato plants and the higher concentrations of the cobalt being hazardous. Also, Basu *et al*., (2006) stated that application of low levels of Co significantly increased the status of macronutrients (N, P and K) in groundnut plants as compared with the higher levels.

Cobalt Content:

Increasing cobalt levels in plant media from 5 up to 15 ppm increased cobalt content in the roots of sweet potato plants grown for two seasons as compared with control treatment (Table 4). These results clearly indicated that cobalt content goes along with the concentration of added cobalt. The obtained results are in good agreement with those obtained by Nadia Gad (2006).

Iron Content:

Results presented in Table (4) indicate that increasing cobalt concentration (from 5 up to 15 ppm) in the plant media resulted in a progressive depression effect on iron content in the tubers of sweet potato plants grown for two seasons. This may be explained on the basis of the obtained results by Blaylock *et al*. (1993) and Nadia Gad (2005 b and 2006) 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 7.5 till 30.0 ppm. They also added that the hazardous effect of cobalt being severely involved in wilting appearance and reduction for net photosynthesis process.

Zinc, Mn and Cu Content:

Presented data in Table (4) show that cobalt level of 10 ppm gave the highest values of Mn, Zn and Cu in sweet potato tubers as compared with cobalt levels of 12.5 and 15 ppm. These results had the same trend of growth, yield and macronutrients (N, P and K) of sweet potato grown for two seasons. Data also show that all the used Co levels significantly increased the content of Mn, Zn and Cu when compared with control.

Confirm these results Nadia Gad (2006) indicated that addition of low Co level of 7.5 ppm had a significant promotive effect for better status of Mn, Zn and Cu in tomato plants. They added that a higher Co concentration has a hazardous effect.

Chemical Analysis of Sweet Potato Roots:

The favorable effect of cobalt on some physiological parameters (carotenoids %, protein %, starch %, mono-sugars %, total soluble sugars % and total soluble solids %,Table 3) as well as macro and micronutrients content in sweet potato roots (Tables 3 and 4) may be due to its effect on increasing carotenoids and ascorbic acid content which are known as antioxidants protecting from cancer and are necessary to several metabolic processes and act as growth regulating factor that influence many biological processes in plants as well as they play as Co-enzyme in the enzymatic reactions by which carbohydrates, fats and proteins are metabolized and involved in photosynsis and respiration processes (Robinson, 1973; Patil and Lall, 1973 and Reda *et al*., 1977).

Conclusion: Cobalt content of sweet potato shoots were generally increased to 2-3 folds that of roots. 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. Levels of 6.36 ppm in the highest cobalt treatment (15.0 ppm) is blow the dangerous level, since the daily consumption of sweet potato roots does not exceed a few grams

Cobalt is promosing element in the newly reclaimed soils and had a significant promotive effect of sweet potato growth, yield, nutrients status and some chemical constituents parameters. From this study it could be suggested that cobalt is consider a beneficial element for higher plants. Therefore, considerable attention should be taken concerning applying this element (Co) as a fertilizer, but further studies are needed to learn more about this element and its mechanisms in soil and plant.

REFERENCES

Abdel-Halim, S.M., 1995. Effect of some vitamins as growth regulators on growth, yield and endogenous hormones of tmato plants during winter. Egypt. J. Appl. Sci., 10(12): 322-334.

Anter, F. and N adia Gad, 2 001. Cobalt absorption in relation to plant water balance. Egypt. J. Soil Sci., 41(1-2): 111-122.

A.O.A.C. 1980. Official Methods of Analysis of the Association of Official Agricultural Chemist 20th Ed. Washigton DC.

Aziz, Eman, Nadia Gad and Nadia Badran, 2007. Effect of cobalt and nickel on plant growth, yield and flavonoids content of *Hibiscus Sabdariffa L.*. Australian J. Basic and Applied Sci., 1(2): 73-78.

Basu, M., P.B.S. Bhadoria and S.C. Mahapatra, 2006. Influence of microbial culture in combination with micronutrient in improving the groundnut productivity under alluvial soil of India. Acta Agric. Slovenica, 87-2, September 2006, pp: 435-444.

Black, C.A., D.D. Evans, L.E. Ensminger, G.L. White and F.E. Clarck, 1982. Methods of Soil Analysais Part 2. Agron. Inc. Madison. Wisc.

Blackmore, L.C., 1972. Methods for chemical analysis of soils New Zealand. Soil Dureanu, P.A.2.1.0, Rep. No. 10.

Blaylock, A.D., T.D. Davis, V.D. Jolly and R.H. Walser, 1993. Influence of cobalt and iron on photosynthesis, chlorophyll and nutrient in regreening chlorotic tomatoes and soybeans. J. Plant Nutr., 8: 823-838.

Chao-Zhou Li, Wang, Di and Wang, Gen-Zuan, 2005. The protective effects of cobalt on potato seedling leaves during osmotic stress. Bot. Bull. Acad. Sin, 46: 119-125.

Chatterjee, J. and C. Chatterjee, 2003. Management of phytotoxicity of cobalt in tomato by chemical measures. Plant Sci., 164: 793-801.

Cottenei, A., M. Verloo, L. Kiekens, G. Velgh and R. Camerlynk, 1982. Chemical Analysis of Plants and Soils. pp: 44-45. State Univ. Ghent Belgium.

FAO 1980. Soil and plant testing as a basis of fertilizer recoomendations. Soils Bull., 3812.

Franceschi, V.R. and N.M. Tarlun, 2002. L-Ascorbic acid is acuumulated in source leaf phloem and transported to sink tissues in plants. Plant Physiol., 130: 649-656.

Gabal, M.R., I.M. Abd-Allah, F.M. Hass and S. Hassannen, 1984. Evaluation of some American tomato cultivars grown for early summer production in Egypt. Annuals of Agric. Sci. Mostohor, 22: 487-500.

Griffiths, H.R. and J. Lunec, 2001. 'Ascorbic acid in the 21st Century-more than a simple antioxidant Enivron. Toxicol. Pharmacol., 10: 173-182.

Hanson, H., T. Larsen, H.M. Seip and R.D. Vogt, 2001. Trace metals in soils at four sites in southern China. Water, Air, Soil Pullut., 130: 1721-1726.

Laila, M. Helmy and Nadia Gad, 2002. Effect of cobalt fertilization on the yield, quality and the essential oil composition of parsley leaves. Arab Univ. J.Agric. Sci. Ain Shams, cairo, 10(3): 803-829.

Locke, J.M., J.H. Bryce and P.C. Morris, 2000. Contrasting effects of ethylene preception and biolsynthesis inhibitors on germination and seedlings growth of barley (*Hordeum vulgare* L.) J. Exp. Bot., 51: 1843-1849.

Muhammed, J. and P.D. Yakub, 2005. Adaptaion and yield stability of sweet potato clones for human and Pig food in mountainous areas of Jayawijaya, Iran. Jaya, Indonesia. Acta Hort. International Soc. for Horticultual Science (ISHC), Leuven, Belgium: 676: 189-197.

Nadia Gad, 2005a. Interactive effect of cobalt and salinity on tomato plants II- Some physiological parameters as affected by cobalt and salinity. Research Journal of Agriculture and Biological Sciences Pakistan. 1(3): 270-276.

Nadia Gad, 2005 b. Effect of cobalt on tomato growth, yield and fruit quality. Egypt. J. Appl. Sci., 20(4): 260-270.

Nadia Gad, 2005 c. Interactive effect of cobalt and salinity on tomato plants I-Growth and mineral composition as affected by cobalt and salinity. Research Journal of Agriculture and Biological Sciences Pakistan., 1(3): 261-269.

Nadia Gad, 2006. Increasing the efficiency of water consumption through cobalt application in the newly reclaimed soils. J. Applied Sci. Resarch, Pakistan 2(11): 1081-1091.

Nadia Gad, A.M. Shafie and M.S. Abdel Fatah, 2008. Effect of cobalt on cucumber growth, fruits yield and mineral composition. J. Agric. Sci. Mansours Univ., 33(1): 909-915.

Panda, S.H., S.K. Naskar and R.C. Ray, 2006. Production, proximate and nutritional evaluation of sweet potato crud. J. Food, Agric. & Environ.. World Food Ltd Helsinki, Finland, 4(1): 124-127..

Pastori, G.M., G. Kiddle, J. Antoniw, S. Bernards, C. Veljovic,-Jovanovic, P.J. Verrier, G. Noctor and W.J. Foyer, 2003. Leaf vitamin C contents modulate plant defense transcript and regulate genes that control development through hormone signaling. Plant Cell, 15: 939-951.

Patil, B.N. and S.B. Lall, 1973. Effect of presowing treatment with L-Ascorbic acid and gibberellic acid on growth and physiolcal constituents of wheat. Botanique (Nagpur), 4, 5770 (Biol. Abst. 57:34).

Rauser, W.E. and A.B. Samarakoon, 1980. Vein loading of *Phaseolus vulgaris* exposed to excess cobalt, Nickel and Zinc. Plant Physio., 65: 578-583.

Reda, F., M. Fadl, R.S. Abdel-All and A. El-Moursi, 1977. Physiological studies on *Ammi visnaga* L. The effect of thiamine and ascorbic acid on growth and chromone yield. Egypt. J. Pham. Sci., 18: 19-27.

Robinson, F.A., 1973. Vitamins In Phytochemisrty. by Miller, L.P. (Editor) Vol. III, 195-220. Van Nostrand Reinhold Co. New York.

Snedecor, G.W. and W.G. Cochran, 1982. Statistical Methods. 7th ed. The Iowa state Univ. press. Ames, Iowa, USA. pp: 365-372.

Tewari, R.K., P. Kumar, P.N. Sharma and S.S. Bisht, 2002. Modulation of oxidative stress responsive enzymes by excess cobalt. Plant Sci., 162: 381-388.

Witte, C.P., S.A. Tiller, M.A. Taylor and H.V. Davies, 2002. Addition of Nickel to Murashiga and Skoog medium in plant tissue culture activites urease and may reduce metabolic stress. Plant Cell Tissue Organ Cult., 86: 103-104.

Young, S.R., 1983. Recent advances on cobalt human nutrition. Victoria Pochvovedeniye, 3: 59-62.