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INFLUENCE OF CADMIUM ON PLANT GROWTH AND SOME NUTRIENTS CONTENT OF LETTUCE PLANT.

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ABSTRACT

A water culture experiment was conducted in summer season 2009 to evaluate the effect of increasing cadmium concentrations; (0.0, 0.5, 1.0 and 1.5 mg l^{-1}) on growth and some nutrients content of tow species of lettuce plant (Lettuce (*lactuca sativa*) and Crisp Lettuce (*lactuca Sativa Varity Crispa*)).

The results could be summarized as follows:

1-The dry matter yield (shoots and roots) of the tow Varieties were decreased by increasing cadmium concentration.

2-Cadmuim uptake by plant was increased by increasing concentration in growth media.

3-Concentration of cadmium in roots was higher than the concentration of shoots for tow species.

4- Excluding Fe content, the Zn, Mn, Cu, P and K decrease with increasing cadmium concentration of plant shoots.

5- Excluding K content, the Zn, Fe, Mn, Cu and P increase with increasing cadmium concentration of plant shoots as compared with the control.

6- The Lettuce (lactuca varity) at the low concentration was higher tolerant more than the Crisp Lettuce Varity; while at the highest concentration the Crisp Lettuce Varity was better in tolerant than the Lettuce Varity.

Keywords: cadmium content, plant tolerant and nutrients content.

INTRODUCTION

In recent years there have been a large number of reports on the presence of heavy metals, including cadmium, chromium, lead and mercury in higher plants. Most of these reports were concerned mainly with environmental pollution. The presence of heavy metals in the food chain and genotypical differences in the critical toxicity levels of heavy metals in plants has been reported (Marschner, 1983). Among heavy metals, which are widespread pollutants of the surface soil layer, cadmium is one of the most toxic. In plants, Cd inhibits root and shoot growth, affects nutrient uptake and homeostasis, and frequently is accumulated by agriculturally important crops (Sanita and Gabrielli, 1999). Thus, Cd is consumed by animals and humans with their diet and can cause diseases. Contamination of soil with Cd also negatively affects biodiversity and the activity of soil microbial communities (McGrath, 1994).

Cadmium is a heavy metal with high toxicity and has an elimination half-life of 10-30 years (Jan, *et al*., 1999). People are exposed to cadmium by intake of contaminated food or by inhalation of tobacco smoke or polluted air (Jarup *et al.,* 1998). High concentrations of cadmium in soils represent a potential threat to human health because it is incorporated in the food chain mainly by plant uptake (Alvarez-Ayuso, 2008).Nriagu and Pacgana (1988) reported that about 22000 tones of cadmium are globally discharged every year in to the soil. Cadmium contamination of the soils is regarded as a great danger for living organisms.

Salt *et al*., (1995) stated that the amount of cadmium that accumulates in plant is limited by several factors including: (1) Cd bioavailability within the rhizosphere, (2) rates of Cd transport into roots *via* either the apoplectic or simplistic pathways, (3) the proportion of Cd fixed within roots as a Cd- phytocchelatin complex and accumulated within the vacuole, and (4) rates of xylem loading and translocation of Cd. While, Grant and Bailey, (1998) indicated that Cd concentrations of durum wheat increased with applications of phosphorus and nitrogen fertilizers. Yang *et al*. (1999) found, in solution culture, Cd concentrations in wheat corn increased with P supply at pH 5.0. Maier *et al*. (2002) reported that P fertilization significantly increased tuber Cd concentrations of potato in glasshouse and field experiments.

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The objective of this study was to evaluate the effect of increasing cadmium concentration on plant growth and some nutrients content of tow lettuce species.

MATERIALS AND METHODS

The study was conducted to determine the effect of cadmium on plant growth, some nutrients content and tolerant of tow lettuce species to increasing Cd levels in nutrient culture under the laboratory conditions during May of 2009 in a Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo. Lettuce cultivars were grown and modified Hoagland nutrient solution (containing: in mmol/L, KNO3, 4; Ca(NO3)2, 4; MgSO4, 1.5; KH2PO4, 1.3; in µmol/L, FeEDTA, 50; CuSO4, 1; MnSO4, 5; H3BO3, 10; Na2MoO4, 0.5; CoSO4, 0.19; NaCl, 100) was used as growth medium. Lettuce (*lactuca sativa*) and Crisp Lettuce (*lactuca Sativa Varity Crispa*) were germinated in sand cultural for 2 weeks. Then the plants were transferred to containers (8 liters per pot) having nutrient solution (stable water culture technique). CdSO4 (as a Cd source) was added to the standard nutrient solutions to give concentrations of 0.0, 0.5, 1.0 and 1.5 mg L^{-1} Cd, after one week in the standard nutrient solution and adjusted pH to 6.0 by using 0.1 mol / L KOH. The plants were grown in a growth chamber with 14/10 h light/dark cycles. Light intensity was about 280 µ mol protons/ (m^2.s). The nutrient solution was renewed twice a week and aerated continuously. The pots were randomly arranged several times during the growth period.

After four weeks of growth (one week from treated), the plants were harvest and washed in distill water, then the plants were divided into shoots and roots, then representative portions were wet digested using a mixture of $HClO_4$ and H_2SO_4 at a rate of 1:1 to determine P, K and micronutrients; total P was determined by ascorbic acid method; total K was determined using flame photometer; according to (Page *et al*., 1982). The micronutrients (Fe, Mn, Zn, Cu and Cd) were determined by Inductively Coupled Plasma Spectrometer (ICP) plasma 400.

The Cd tolerance indices were calculated according to the following equation of Das *et al*., 1999 (Table, 3).

$$\text{Tolerance indexes} = \frac{\text{Growth (dry matter) increase in Cd level}}{\text{Growth (dry matter) in nutrient solution without Cd}} \times 100$$

RESULTS AND DISCUSSION

Data presented in Table (1) show that the dry matter yield of shoots were affected by the cadmium treatments; the highest values of dry matter yield were recorded with the low concentration of cadmium as compared with the highest concentration and the control. Also, data reveal that the mentioned trend of dry matter yield of Lettuce shoots was observed for dry matter yield of Crisp Lettuce shoots. The decreases in dry matter shoots as a result of Cd treated were associated with pronounced decreases in shoot height and root length. This might be attributed to its effects on cell division and/or cell expansion, and might be through its effect on DNA and RNA synthesis. Furthermore, any change in the growth rate which results from increasing Cd supply must be dependent on the change in the rate of net photosynthesis that reduces the supply of carbohydrates or proteins and consequently decreases the growth of the plant. A this finding is confirmed by the work of Skorzynska and Baszynski (1995) who working on bean plant, pointed out that the application of Cd resulted in reduction of photosynthesis efficiency and transpiration.

On the other hand, Wilson (1992) stated that the reductions in dry matter yield of mustard plants have been attributed to the direct effect of higher Cd concentrations in plant tissue and not through an indirectly induced deficiency of other nutrients. Also, Ozturk *et al*. (2003) found that Cd supply reduced shoot and root dry matter production. The results are in harmony with Abo Kassem *et al*., (1997) who suggested that, the shoot and root dry weight and the relative growth rate on wheat were significantly reduced by 5 and 10 m M Cd and the application of Cd resulted in reduction of photosynthesis and transpiration.

Table 1: Effect of cadmium on dry matter yield and some nutrients content of studied plants shoot.

Treatments mg/l	D.W g/plant	Ions mg/plant						
		Cd	Zn	Fe	Mn	Cu	P	K
	Lettuce							
Control	0.21	0.03	27.24	40.21	25.21	1.52	347	1062
0.5	0.18	29.55	25.34	41.35	30.91	1.30	338	1022
1.0	0.14	30.86	23.81	56.94	36.25	1.20	343	936
1.5	0.12	33.64	27.90	77.05	25.65	1.15	331	945
Crisp Lettuce								
Control	0.26	0.04	29.22	42.82	24.71	1.63	402	1134
0.5	0.19	36.60	30.70	43.75	26.65	1.71	369	1098
1.0	0.17	43.90	27.45	62.69	28.10	1.45	382	1100
1.5	0.13	39.75	24.55	67.41	28.23	1.35	352	1016

On the other hand, the cadmium uptake was increased with increasing concentration of both plants**,** while zinc content in plants decreased by increasing cadmium concentration. This might be attributed to**;** the level of nutrients absorbed by plants is related to the amount of available nutrients in the growth medium. While, uptake of nutrients increases for some nutrients or decreases for the others depending on antagonistic or synergistic (interactions) effects among plant nutrients; in this concern, Yildiz, (2005) stated that, the chemistry of Cd and Zn are similar to each other. Therefore, a special importance has been given for both elements.

Concerning the effect of cadmium on other nutrients, data in table 1 reveal that the iron and magnesium content increased of both plants with increasing concentration of cadmium, while the concentration of copper, phosphorus and potassium were decreased with higher concentration of cadmium as compared with the control. These results are in harmony with those, Liu *et al*. (2006) and Hernandez *et al*., (1998) who found that Fe in pea plants was higher than that recorded in the control plants after the treatment with 50 µM Cd. The relationship between Fe and Cd uptake is significant, as reported by Lombi *et al*., (2002) in both short and long-term studies revealed that Cd uptake was significantly enhanced by Fe deficiency in the Ganges ecotype. Also, Rudio *et al*., (1994) who mentioned that the rice cv. *Baha* plant accumulated large quantities of Cd and Ni when growing for 10 days in nutrient solution containing these heavy metals also induced a decrease in K, Ca and Mn content in the plants.

In roots, data in table (2) show that the mentioned trend of dry matter yield of shoots was observed for roots abut, dry matter yield, while the cadmium content in roots was higher than the shoots. In this concern, Mahmood *et al*., (2009) stated that the roots of faba bean and wheat respectively accumulated Cd at higher levels than shoots, indicating that the roots acted as barrier restricting Cd transport. A similar finding is reported by Liu *et al*., (2006) who found that the Cd levels in roots and shoots of cultivars of maize increased significantly with increasing Cd concentration. In addition, Cd was concentrated mainly in the roots, and small amounts of Cd were transferred to the shoots. Generally it is important to mention that in Lettuce plants, the decreases in shoot or root dry weights as a result of Cd addition were associated with pronounced decreases in shoot height and root length. This might be attributed to its effects on cell division and or cell expansion which may be through its effect on DNA and RNA synthesis**.** Also**,** Li *et al*., (2008) stated that the significant reduction in root growth of *A. lebbeck* with the increase in concentration of cadmium treatment was also observed as compared to control. He added, cadmium is a highly toxic contaminant that affects many plant metabolic processes. Cadmium can also affect root metabolism, which shows sensitivity to Cd^{2+} toxicity by a reduction in lateral root size (Wojcik and Tukendorf, 1999). This is due to reductions in both new cell formation and cell elongation in the extension region of the root (Prasad, 1995; Liu, *et al*., 2004).

Table 2: Effect of cadmium on dry matter yield and some nutrients content of studied plants root.

Treatments mg/l	D.W g/plant	Ions mg/plant						
		Cd	Zn	Fe	Mn	Cu	P	K
	Lettuce							
Control	0.11	0.05	17.81	36.21	7.18	2.81	287	1006
0.5	0.09	134.85	19.21	38.00	9.90	3.00	263	956
1.0	0.07	145.35	25.15	42.32	13.45	3.95	267	847
1.5	0.05	168.40	31.87	46.50	13.70	4.12	234	831
Crisp Lettuce								
Control	0.10	0.05	21.38	37.35	9.72	3.95	298	1260
0.5	0.10	109.85	23.50	56.12	12.54	4.15	286	1065
1.0	0.09	117.55	32.45	69.15	14.45	4.30	266	1130
1.5	0.07	126.43	34.58	63.20	15.20	5.85	243	987

Gregory and Atwell, (1991) stated that the composition and quantity of root exudates vary from plant to plant, with two factors being important. One is a plant's inherent biology, such as plant species, growth and developmental period, and nutrient status. The other is the external environment for plant growth, i.e. soil and its elemental content. With regard to the effect of cadmium on other nutrients data revealed that, the zinc, iron, magnesium and copper increased with addition of cadmium in growth media. While phosphorus and potassium decreased with increasing cadmium concentration. These results are in harmony with those, Yildiz, (2005) and Liu *et al*. (2006). Generally, the efficiency of metal accumulation is dependent on two main factors. First, plants must be able to take up and accumulate high concentrations of metals, and secondly they must be able to produce a large biomass. Unfortunately, even the growth of metal-resistant metal-accumulating plants can be severely inhibited when the concentration of available metal in the contaminated soil is very high. This will consequently result in a decrease in plant biomass and, thereby, in the efficiency of phytoremediation, (Li *et al*. 2007).

Concerning the Lettuce and Crisp Lettuce of Cd tolerance, data in table 3 revealed that the Lettuce Variety at the low concentration (0.5 mg/l^{-1}) of cadmium were higher tolerance more than the Crisp Lettuce Varity; while with the highest concentration (1.0 and 1.5 mg/l^{-1}) of cadmium the Crisp Lettuce Variety was better in tolerance than the Lettuce Varity.

Table 3.Tolerance indexes of tow species

Treatments mg/l	**Lettuce**	**Crisp Lettuce**
Control	100.00	100.00
0.5	84.37	80.55
1.0	65.62	72.22
1.5	53.12	55.55

In this concern, Hall (2002) stated that the differences in root uptake and shoot accumulation of Cd could be an important factor in explaining genotypic variations in tolerance to Cd toxicity. Therefore, the selection of plant genotypes with high ability to repress root uptake and shoot transport of Cd is a reasonable approach to alleviate adverse effects of Cd toxicity in crop plants. It is important to know the different Cd toxicity resistances among genotypes and the potential of Cd accumulation as well as their physiological responses to Cd toxicity.

REFERENCES

Abo Kassem, E., A. Sharaf El-Din, A. Mohamed and E. Foda. (1997). Effect of different cadmium concentration on growth photosynthesis and ion relation of wheat. Egypt J. Physiol. Sci., 21: 41-51.

Alvarez, Ayuso, E. (2008). Cadmium in soil-plant systems: an overview. International Journal of Environment and Pollution, 33(2-3): 275-291.

Das, P., S. Samantaray and G.R. Rout. (1999). Studies on Cd toxicity in plants: A review. India.

Eriksson, J. E. (1990). Factors influencing adsorption and plant uptake of cadmium from agricultural soils. Swedish University of Agricultural Sciences, Department of Soil Sciences, Reports and Dissertations 4. Uppsal, Sweden.

Grant, C.A. and L.D. Bailey, (1998). Nitrogen, phosphorus and zinc management effects on grain yield and cadmium concentration in two cultivars of durum wheat. Canada J. Plant Sci, 78(1):63-70.

Grant, C. A., Bailey, L. D. and Therrien, M. C. (1996). Effect of N, P, and KCl fertilizers on grain yield and Cd concentration of malting barley. Fert. Res. 45: 153–161.

Gregory, P.J. and B. J. Atwell, (1991). The fate of carbon in pulse-labeled crops of barley and wheat. Plant and Soil 136, 205–213.

Hall, J. L. (2002). Cellular mechanisms for heavy metal detoxification and tolerance. J. Exp. Botany. 53: 1-11.

Hernandez, L.E., E. Lozano-Rodríguez, A. Gárate and R. Carpena-Ruiz (1998). Influence of cadmium on the uptake, tissue accumulation and subcellular distribution of manganese in pea seedlings. *Plant Sci.,* 132: 139-151.

Jan, A.S., H.A. Roels, D. Emelianov, T. Kuznetsova, L. Thijs, J. Vangronsveld and P. Fagard (1999). Environmental exposure to cadmium, forearm bone density, and risk of fractures: prospective population study for the Public Health and Environmental Exposure to Cadmium. The Lancet*,* 353(9159): 1140-1144.

Jarup, L., M. Berglund, C.G. Elinder, G. Nordberg and M. Vahter, (1998). Health effects of cadmium exposure a review of the literature and a risk estimate, Scandinian Journal of Work, Environment and Health, 24 (1): 1–5.

Li, M., L.J. Zhang., L. Tao and W. Li, (2008). Ecophysiological responses of Jussiaea rapens to cadmium exposure, Aquatic Botany*,* 88(4): 347-352.

Li, W. C.,Ye, Z. H. and M. H. Wong, (2007). Effects of bacteria on enhanced metal uptake of the Cd/Zn-hyperaccumulating plant, Sedum alfredii. Journal of Experimental Botany. 58 (15/16) 4173 – 4182.

Liu, D., W. Jiang and X. Gao. (2004). Effects of cadmium on root growth, cell division and nucleoli in root tips of garlic, Physiologia Plantarum, 47: 79-83.

Liu, D.H., M. Wang, J.H. Zou and W.S. Jiang, (2006). Uptake and accumulation of cadmium and some nutrient ions by roots and shoots of maize (*Zea mays* L.). Pak. J. Bot., 38: 701-709.

Lombi, E., K.L. Tearall, J.R. Howarth, F.J. Zhao, M.J. Hawkesford and S.P. McGrath (2002). Influence of iron status on cadmium and zinc uptake by different ecotypes of the hyperaccumulator *Thlaspi caerulescens.* Plant Physiol*.,* 128: 359-1367.

Mahmood, T., K.J. Gupta and W.M. Kaiser, (2009). Cadmium stress stimulates nitric oxide production by wheat roots. Pak. J. Bot., 41: 1285-1290.

Maier, N.A., M.J. McLaughlin, M. Heap, M. Butt and M.K. Smart, (2002). Effect of current-season application of calcitic lime and phosphorus fertilization on soil pH, potato growth, yield, dry matter content, and cadmium concentration. Communications in Soil Science and Plant Analysis, 33(13-14):2145-2165.

Marschaner, M. (1983). Mineral nutrition of higher plants. Institute of Plant Nutrition, Hohenheim Federal Republic of Germany, Academic Press, London.

McGrath, S.P. (1994). Effects of heavy metals from sewage sludge on soil microbes in agricultural ecosystems, in: Ross, S.M. (Ed.), Toxic Metals in Soil–Plant Systems. Wiley, New York, pp. 247–273.

Nriagu, J. O. and J. M. Pacgana (1988). Quantitative assessment of worldwide contamination of air, water and soils of trace metals. Nature 333: 134-9.

Ozturk, L., S. Eker, F. Ozkutlu (2003). Effect of cadmium on growth and concentrations of cadmium, ascorbic acid and sulphydryl groups in durum wheat cultivars. Turk. J. Agric. For. 27: 161- 168.

Page, A. L., R. H. Miller and D. R. Keeny (1982). Methods of soil analysis. Part п. Chemical and microbiological properties (2nd ed.) Amer. Soc. Agron. Monograph no. 9 Madison, Wisconsin, USA.

Prasad, M.N. (1995). Cadmium toxicity and tolerance in vascular plants, Environmental and Experimental. Botany, 35: 525-545.

Rahaman,A. K., M.S. Alam, M.J.A. Mian and M.E. Haque (2007). Effect of different fertilizers on concentration and uptake of cadmium by rice plant. J. Agric. Res., 45(2)129-134.

Rudio, M., I. Escrig, G. Martine, C. Lopez, F. Bent and A. Sanz (1994). Cd and Ni accumulation in rice plant, Effects on mineral nutrition and possible interaction of abscisic and gebberelic acid. *Plant Growth Regul.,* 14: 151-157.

Salt, D.E., R.C. Prince, I.J. Pickering and I. Raskin (1995). Mechanisms of cadmium mobility and accumulation in Indian Mustard. Plant Physiol., 109: 1427-1433.

Sanita d. T. and R. Gabrielli (1999). Response to cadmium in higher plants. Environmental and Experimental Botany 41, 105–130.

Skorzynska, E. and T. Baszynski, (1995). Some aspects of rammer bean plant response to cadmium at different stages of the primary leaf growth. Acta Soc. Bot. Polon., 64: 165-170.

Watanabe, Y., Z.W. Zhang, J.B. Qu, G.F. Xu, L.H. Song, J.J. Wang, S. Shimbo, H. Nakatsuka, K. Higashikawa, and M. Ikeda, (1998). Urban–rural comparison on cadmium exposure among general populations in Shandong Province, China. Sci. Total Environ., 217:1-8.

Wilson, N. J. (1992). Accumulation of cadmium in crop plants and its consequences to human health. Agron. 51: 173-212.

Wojcik, M. and A. Tukendorf (1999). Cd-tolerance of maize, rye and wheat seedlings, Acta Physiologia. Plantarum, 21: 99-107.

Yang, Z.M., S.J. Zheng, and A.T. Hu, (1999). Effects of different levels of P supply and pH on the content of cadmium in corn and wheat plants. Journal of Nanjing Agricultural University, 22(1):46-50 (in Chinese).

Yildiz, N. (2005).Response of tomato and corn plants to increasing Cd levels in nutrient culture. Pak. J. Bot., 37(3): 593--599.

تأثيرالكادميوم على نمو نبات الخس ومحتواه من بعض العناصر الغذائيه .

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أقيمت تجربة مزارع مائيه خلال صيف موسم 2009 م لتقييم تأثير زيادة تركيز عنصر الكادميوم على نمو النبات، وامتصاص العناصر وكذلك تحمل النبات للتأثير الضار لهذا العنصر. وكانت التركيزات المستخدمه هى صفر- 0,5 - 1,0 – 1.5 مليجرام/لتر على صنفين من نبات الخس (الخس البلدى و الجريت ليكس).

وكانت أهم النتائج تتلخص فيما يلى :.

- سجلت المادة الجافه أقل القيم مع زيادة تركيز عنصر الكادميوم فى بيئة النمو مقارنة بالكنترول.
- زاد تركيز عنصر الكادميوم فى كلا أجزاء الصنفين وكان التركيز فى الجذور أعلى من السيقان والاوراق.
- فى سيقان واوراق كلا الصنفين باستثناء عنصر الحديد فقد نقص تركيز كلا من عنصر الزنك، الماغنيسيوم، النحاس، الفوسفور والبوتاسيوم بزيادة تركيز عنصر الكادميوم فى بيئة النمو بالمقارنه بالكنترول.
- فى جذور كلا الصنفين باستثناء عنصر البوتاسيوم فقد زاد تركيز كلا من عنصر الزنك، الحديد، الماغنيسيوم، النحاس والفوسفور بزيادة تركيز عنصر الكادميوم فى بيئة النمو.
- بالنسبه لتحمل كلا الصنفين للتأثير الضار لعنصر الكادميوم فقد وجد أنه فى التركيز المخفف كان تحمل الصنف البلدى أفضل من صنف الجريت ليكس ،بينما فى التركيزات العالية فقد وجد العكس حيث سجل صنف الجريت ليكس قيما أفضل بالمقارنه بالكنترول والصنف البلدى .

قام بتحكيم البحث

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