Middle East Journal of Applied Sciences, 4(4): 1110-1117, 2014
ISSN: 2077-4613

Effect of Cadmium on Yield, Nutrient Contents and Toxicity Tolerance of Some Rice Varieties

[1]A. H. Rizk, [2]E. I. Zaazaa and [1]S. S. Shawer

[1]Soils and Water Department, Faculty of Agriculture, Al– Azhar University, Cairo, Egypt.
[2]Agronomy Department, Faculty of Agriculture, Al– Azhar University, Cairo, Egypt.

ABSTRACT

A sand culture experiment carried out under greenhouse conditions during May 2013 at the Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt. The experiment aimed to study the effect of Cd concentration in growth media on growth, some nutrients content and tolerant index. Three concentration of cadmium (1.00, 2.00 and 3.00 mg.l^{-1} and four rice varieties (Sakha 106, Sakha 104, Giza 177 and Giza 187) were used.

The results could be summarized as follows: The highest values of roots, shoots and grains dry matter yield were recorded with the low concentration of cadmium as compared with the highest concentration. The highest values of cadmium uptake were recorded in roots and the lowest values in grain. Cadmium uptake and accumulation in plant parts increased with increasing concentration. Nitrogen, potassium and micronutrient of rice roots, shoots and grains significantly decreased with increasing cadmium concentration in the growth media. The yield of rice grain was highly affected by cadmium treatments. At the low concentration of cadmium (1 and 2 mg.l^{-1}) in growth media the best values of tolerant were recorded with Giza 178, followed Giza 177 more than Sakha 106 and Sakha 104; while, at the high concentration (3 mg.l^{-1}) the best values of tolerance were recorded with sakha 104, followed Giza 178, then Giza 177 better than Sakha 106 compared to control.

Key words: Rice plant, cadmium toxicity, Nutrient contents, tolerant index.

Introduction

Rice is one of the most important staple foods which are the staff of life for 3 billion people in the world, especially in East and South Asia, the Middle East, Latin America, and the West Indies (Stone, 2008). In Egypt, rice constitutes one of the main agricultural exports. During year 2012, the area cultivated with rice was 1.42 million hectare with an average of 4.15 t.fed^{-1}, and total production of 5.89 million tons (RRTC 2012). However, many biotic and a biotic stresses cause negative impacts on its production and quality. Heavy metals contamination in rice fields is an important problem directly posing serious health risk for human beings (Rogan *et al.*, 2009; Cao *et al.*, 2010). Cadmium (Cd) is one of most toxic elements in nature and is soluble and non-degradable contamination which can be transformed from soil to plants (Satarug *et al.*, 2003). (Lidon and Henriques, 1991) stated that, the Cadmium is a toxic element with no known physiological function in plant metabolism; however, Cd generally inhibits plant growth and influences nutrient distribution. 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). Cadmium is a non-essential element for crop plants, it is easily taken up by plants growing on Cd-supplemented or Cd-contaminated soils, entering food chain and causing damage to plant and human health. It has been reported that mean concentration of Cd ranges in plant from 0.013 to 0.22 mg/kg^{-1} for cereal grains, 0.07 to 0.27 mg.kg^{-1} for grasses, and 0.08 to 0.28 mg.kg^{-1} for legumes (Kabata-Pendias and Pendias, 2001)

De Maria *et al.* (2013) studied the effects of soil cadmium contamination on Cd accumulation and distribution; they stated that, Cd concentration in roots always exceeded those in the aboveground dry matter with a low translocation from roots to shoots. At early stage of growth, Cd concentration in plants was higher than at the flower bud stage. Farooqi *et al.* (2009) stated that the seed germination, root, shoot and seedling length, root shoot ratio and dry biomass of *Albizia lebbeck L.*, were significantly decreased with the treatment of Pb and Cd at 10, 30, 50, 70 and 90 μmol/L as compared to control and the tolerance of *Albizia lebbeck* seedlings to lead and cadmium gradually decreased with the increasing concentrations of lead and cadmium as compared to control. (Sandalio *et al.,* 2001) stated that the cadmium is easily taken up by plant roots and can be loaded into the xylem for its transport into leaves; a large number of studies have demonstrated the toxic effect of cadmium on plant metabolism, such as a decrease in the uptake of nutrient elements and changes in nitrogen metabolism; also, they added that the excessive amount of Cd may cause decreased uptake of nutrient elements,

Corresponding Author: A. H. Rizk, Soils and Water Department, Faculty of Agriculture, Al– Azhar University, Cairo, Egypt.
E-mail: drahmed.hamedy@yahoo.com

inhibition of various enzyme activities and induction of oxidative stress including alterations in enzymes of the antioxidant defense system.

Generally it is important to mention that in carrot plants, the decreases in shoot or root fresh and dry weights as a result of Cd soil 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. In addition, Abo Kassem *et al.* (1997) suggested that, the root and shoot dry weight and the relative growth rate of wheat were significantly reduced by 5 and 10 μmol Cd and the application of Cd resulted in reduction of photosynthesis and transpiration. The gradual decreases in the specific utilization rate were found in the plants treated with the three doses of Cd soil addition either alone or combined with any of the three dose of Zn soil addition when compared with control-Cd untreated plants.

Veselov *et al.* (2003) stated that the cadmium treatment led to an inhibition of growth rate, transpiration and ion uptake by wheat seedlings; the rapid inhibition of root function was evident in terms of reductions in both ion and water uptake. They added, the decrease in transpiration of Cd-treated plants is likely to be due to stomata closure. Cd-induced reduction in stomata conductivity is in accordance with the literature (Pearson and Kirkham, 1981). Its physiological significance might be in limiting water losses when water uptake by roots is reduced by Cd. A beneficial effect of decreased stomata conductivity was assumed to be in limiting Cd transported with the transpiration flow (Salt *et al.,* 1995). Free Cd ions in the cytosol can be toxic to plant cells. In plant cells, cadmium tends to be stored in the apoplast and in vacuoles, which may contribute to Cd tolerance in hyper accumulator plants and common crops (Boominathan and Doran, 2003; Liu *et al.,* 2007). Cadmium may cause growth inhibition related to reduction of mitotic activity, induction of chromosome aberrations, toxicity to nucleoli in apical meristems (Qin *et al.,* 2010), damage of macromolecules, mainly proteins and lipids (Li *et al.,* 2005), and disturbance of the organization of the microtubular cytoskeleton in interphase and mitotic cells (Jiang *et al.,* 2009; Liu *et al.,* 2009). Cataldo *et al.* (1983) reported that, the normally cadmium ions are mainly retained in the roots and only small amounts are transported to the shoots. Roots of the plant acts as a barrier against heavy metal translocation and this may be a potential tolerance mechanism operating in the roots, Ernst *et al.* (1992).

Cadmium (Cd) is highly toxic to human, animals and plants. In plants exposure to Cd causes reductions in photosynthesis, water and nutrient uptake (Sanita di Toppi and Gabbrielli, 1999). As a consequence, Cd-exposed plants show various symptoms of injury such as chlorosis, growth inhibition, browning of root tips and finally death (Kahle, 1993). The objective of the present study was to evaluate the effect of Cd on growth, some nutrients content and yield among four Egyptian rice varieties, also to determine the ability of some Egyptian rice varieties for toxicity tolerance of cadmium.

Materials and Methods

A sand culture experiment was carried out using a randomized complete block design with three replicates under greenhouse conditions during May of 2013 in a Faculty of Agriculture, Al-Azhar University, Cairo,Egypt. Four Egyptian rice Varieties (Sakha 106, Sakha 104, Giza 177 and Giza 178) were used in this study and represented a wide range of diversity in several of characters (Table 1). Ten rice kernels variety were planted in each pot; Rice cultivars were grown and modified 0.25 Hoagland base nutrient solution was used as growth media. Pots were irrigated daily to adjust its moisture at saturation percent. After 10 days, seedlings were thinned to five plants per pot. $CdSO_4$ (as a Cd source) was added to the standard nutrient solutions to give concentrations of 1.0, 2.0 and 3.0 mg. L^{-1} Cd to irrigate the rested plants.

At the end of the experiment in September 2013, the plants were harvested, plant samples were collected and washed with distilled water, dried at 70ºc and ground, then representative portions were wet digested using $HClO_4$ and H_2SO_4 acids to determine N, K and micronutrients; total N was determined by micro-Kjeldahl technique and total K was determined using flame photometer according to Page *et al.* (1982). The Cd and micronutrients (Fe, Mn, Zn and Cu) Cd were determined by Inductively Coupled Plasma Spectrometer (ICP) plasma 400.
The Cd tolerant index was calculated according to the following equation of Das *et al*. (1999).

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

The statistical analysis for all data obtained was carried out and differences between means were calculated using L.S.D. test according (Snedecor and Cochran, 1980).

Table 1: Origin and characteristics of the rice varieties.

No.	Varieties	Origin (Parentage)	Characteristics
1	Sakha 106	Egypt (Giza 177/Hexi 30).	Japonica type, early maturity, short grin, high yielder, good grain quality.
2	Sakha 104	Egypt (GZ40968-1/GZ41009-1).	Japonica type, early maturity, recommended growing in normal and saline soils, short grin, high yielder, good grain quality.
3	Giza 177	Egypt (Giza 171/yomji No.1//pi, No.4).	Japonica type, early maturity, smi- dwarf, short grin, high yielder, good grain quality.
4	Giza 178	Egypt (Giza 175/Milyang 49).	Indica /Japonica type, 135 days growth total duration, tolerant to salinity, short grin, high yielder, good grain quality.

Result and Discussion

A- Effect of Cd treatments on roots and some nutrient contents of rice plant.

Data presented in table (2) show that the dry matter of roots were affected by the cadmium treatments; the highest values were recorded with the low concentration of cadmium compared with the highest concentration and the control. The values of dry matter were 1.96, 1.95, 1.80 and 1.63 g/ plant obtained at the control and decreased to 0.78, 0.72, 0.85 and 0.67 g/plant with 3 $mg.l^{-1}$ cadmium concentration of sakha 106, sakha 104, Giza178 and Giza 177, respectively. The decrease in dry matter roots as a result of Cd treated were associated with pronounced decreases in root length in this concern, Liu *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 that, cadmium is a highly toxic contaminant that affects many plant metabolic processes; root metabolism, which shows sensitivity to Cd^{2+} toxicity by a reduction in lateral root size, 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). Also, Rascio *et al.* (2008) reported that treatment of rice seedlings with Cd led to inhibition of root growth and alterations in their morphogenesis. In pea plants, the Cd stress also caused disorders in root elongation and the mitotic process and caused chromosomal aberrations of root tips.

Concerning the effect of cadmium concentration in growth media on cadmium uptake by rice roots, data in table 2 reveal that, the cadmium uptake and accumulation were increased with increasing concentration. The values of cadmium uptake were 0.123, 0.142, 0.122 and 0.121 mg/kg at 1ppm concentration, and increased to 0.215, 0.257, 0.263 and 0.16 mg/kg at3ppm concentration of sakha 106, sakha 104, Giza178 and Giza 177, respectively. The results are in harmony with (Rizk, 2010).

Table 2: Effect of Cd treatments on dry matter of roots and their content of nutrients.

Variety	Treatments of Cd ($mg.l^{-1}$)	*D.W. of roots g/plant	Cd (mg/kg. d.w.)	N and K content (%)		Micronutrients (mg / kg. d.w.)		
				N	K	Fe	Mn	Zn
Sakha 106	0	1.96	0.017	0.320	0.54	3.240	0.289	2.482
	1	1.76	0.123	0.250	0.59	3.163	0.234	2.113
	2	1.17	0.126	0.250	0.51	3.021	0.176	2.096
	3	0.78	0.215	0.180	0.53	2.929	0.196	1.825
	Mean	1.41	0.120	0.250	0.542	3.088	0.224	2.129
Sakha 104	0	1.95	0.019	0.330	0.510	3.299	0.290	2.982
	1	1.62	0.142	0.310	0.430	3.188	0.184	3.090
	2	0.95	0.165	0.320	0.420	3.085	0.149	2.451
	3	0.72	0.257	0.320	0.460	3.152	0.162	2.602
	Mean	1.31	0.146	0.321	0.515	3.181	0.196	2.781
Giza 178	0	1.80	0.019	0.330	0.540	3.125	0.235	2.871
	1	1.85	0.122	0.320	0.550	3.112	0.215	2.561
	2	1.47	0.132	0.280	0.510	2.996	0.125	2.854
	3	0.85	0.263	0.240	0.460	2.254	0.121	1.892
	Mean	1.49	0.134	0.293	0.477	2.955	0174	2.545
Giza 177	0	1.63	0.016	0.340	0.500	3.341	0.254	2.624
	1	1.21	0.121	0.280	0.490	3.251	0.235	2.256
	2	0.97	0.146	0.210	0.470	3.254	0.251	1.985
	3	0.67	0.161	0.260	0.410	3.192	0.224	1.326
	Mean	1.12	0.111	0.263	0.465	3.260	0.241	2.048
Mean of Cd treatments	0	1.835	0.018	0.323	0.514	3.251	0.267	2.740
	1	1.610	0.127	0.281	0.515	3.178	0.217	2.505
	2	1.140	0.142	0.266	0.477	3.172	0.175	2.346
	3	0.755	0.244	0.258	0.465	2.882	0.175	1.911
LSD at 5% level	A	0.011	0.019	0.028	0.016	0.12	0.00085	0.56
	B	0.011	0.019	0.028	0.016	0.12	0.00085	0.56
	A×B	0.022	0.039	0.042	0.033	0.24	0.00169	0.59

**D.W: dry weight*

With regard to the effect of cadmium concentration on nitrogen and potassium content data in the same table show that, the nitrogen and potassium content of rice roots were significantly decreased with increasing cadmium concentration of four rice variety compared with control. The highest values for nitrogen were 0.32, 0.33, 0.33 and 0.34 % obtained at control of sakha 106, sakha 104, Giza178 and Giza 177, respectively. While, the highest values for potassium were 0.59 and 0.55% at $1 mg.l^{-1}$ cadmium concentration of sakha 106 and Giza178, respectively, compared with control and other treatments. These results confirmed with data obtained by Veselov *et al.* (2003) who reported that the uptake of potassium and nitrate, transpiration and shoot growth of wheat plant were inhibited by adding cadmium to the nutrient medium.

Also, the data revealed that the mentioned trend of N and K content was observed for Fe, Mn and Zn content of rice root. The highest values of Fe, Mn and Zn content were obtained at control and decreased with cadmium under the four rice varieties. These results are in agreement with Metwally *et al.* (2005) who stated that, in pea plants, the uptake of P, K, S, Ca, Zn, Mn, and B was inhibited strongly after Cd exposure; while, Guo *et al.* (2007) found that, the treatment of barley plants with 1.0 μM Cd decreased the concentrations of P, K, Ca, Mg, Cu, Fe, Mn, Zn, Mo, and B in roots.

B- Effect of Cd treatments on straw yield and their content of some nutrients.

Data in Table 3 reveal that the straw dry matter yield of rice plant were significantly affected by cadmium treatments; the highest values of dry matter yield were 5.25, 4.85, 4.23 and 4.32 g/plant obtained at control, and decreased to 2.72, 3.02, 2.48 and 2.24 g/plant with $3 mg.l^{-1}$ cadmium concentration for sakha 106, sakha 104, Giza178 and Giza 177, respectively. These decreases might be attributed to its effects on cell division and/or cell expansion, and may be through its effect on DNA and RNA synthesis; consequently, any change in the growth 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 plant. These results are in agreement with Liu *et al.* (2008) and Wilson (1992) stated the yield reductions in 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, Skorzynska and Baszynski (1995) who worked on bean plant pointed out that, the application of Cd resulted in reduction of photosynthesis efficiency and transpiration.

Table 3: Effect of Cd treatments on straw yield and their content of some nutrients.

Variety	Treatments of Cd ($mg.l^{-1}$)	D.W. of straw g/plant	Cd (mg/kg. d.w.)	N and K content (%)		Micronutrients (mg/kg. d.w.)		
				N	K	Fe	Mn	Zn
Sakha 106	0	5.25	0.011	1.63	1.99	0.621	0.649	10.338
	1	4.01	0.023	1.56	1.79	0.616	0.545	9.284
	2	3.56	0.039	1.46	1.10	0.574	0.507	9.238
	3	2.27	0.051	1.39	1.12	0.580	0.519	9.184
	Mean	3.773	0.031	1.51	1.50	0.598	0.555	9.508
Sakha 104	0	4.85	0.013	1.65	1.23	0.638	0.594	10.381
	1	3.81	0.034	1.63	1.10	0.488	0.596	9.251
	2	3.55	0.045	1.64	1.70	0.521	0.570	9.203
	3	3.02	0.057	1.39	0.98	0.455	0.503	8.501
	Mean	3.807	0.038	1.57	1.32	0.517	0.565	9.334
Giza 178	0	4.23	0.011	1.60	1.38	0.363	0.554	10.301
	1	3.93	0.032	1.53	1.29	0.584	0.672	9.241
	2	3.52	0.054	1.41	1.22	0.581	0.821	8.225
	3	2.48	0.063	1.12	1.28	0.567	0.569	8.224
	Mean	3.540	0.040	1.415	1.29	0.524	0.654	8.998
Giza 177	0	4.32	0.012	1.59	1.40	0.681	0.612	9.925
	1	3.70	0.023	1.53	1.15	0.563	0.623	8.556
	2	3.17	0.046	1.46	1.18	0.536	0.713	8.254
	3	2.24	0.061	1.33	1.23	0.565	0.503	8.234
	Mean	3.358	0.035	1.480	1.240	0.586	0.613	8.742
Mean of Cd treatments	0	4.633	0.012	1.618	1.500	0.567	0.602	10.236
	1	3.863	0.028	1.562	1.400	0.563	0.609	9.083
	2	3.450	0.046	1.495	1.300	0.553	0653	8.730
	3	2.502	0.058	1.308	1.153	0.542	0.524	8.533
LSD at 5% level	A	n.s	0.00088	n.s	0.099	0.012	0.0007	n.s
	B	n.s	0.00088	n.s	0.099	0.012	0.0007	0.799
	A×B	0.450	0.00177	n.s	0.198	0.024	0.0015	n.s

Concerning the effect of cadmium concentration in growth media on cadmium accumulation by rice straw, data in table 3 reveal that, the cadmium accumulation were increased with increasing concentration; and the lowest values of cadmium content in straw compared with the highest values of roots at four variety. In this concern, Abdel-Latifbn (2008) found that the concentration of Cd^{2+} in roots was about two fold higher than in shoots during the time of exposure, and he added that, In Wheat seedlings, uptake of ions, chlorophyll content, shoot and root growth were inhibited by adding 0.05mM cadmium to the nutrient medium. Also, Murakami *et al.* (2007) stated that, Cadmium accumulation by roots was higher than by stems. This was as well consistent with the accumulated cadmium uptakes by three other plants; rice, soybean and maize, that were grown in soil contaminated by cadmium. The highest values of cadmium content of shoots were 0.063 and 0.061 mg/kg which obtained with 3 mg.l^{-1} cadmium concentration of Giza 178 and Giza 177 variety, respectively, compared with the other treatments and control.

Regarding the effect of cadmium concentration on nitrogen and potassium content in straw, data in table (3) show that, the highest values of nitrogen and potassium content of rice were recorded with control and low concentration of cadmium treatment. The lowest values of nitrogen and potassium content of straw were obtained at 3 mg. L^{-1} Cd concentration treatment for Giza 178 (1.12% N) and sakha 104 (0.98% K) compared with the control and other treatments. In this concern, Yourtchi *et al.* (2013) found that, the N and K content of treated plants by Cd were decreased as Cd level increased in the soil. Lindberg and Wingstrand (1985) stated that, the decreases in K concentrations may be related to ATPase, responsible for active K uptake. Also Hernandez *et al.* (1996) reported that, the Cd also reduced the absorption of nitrate and its transport from roots to shoots, by inhibiting nitrate reductase activity in the shoots.

Also, data in table 2 reveal that the lowest values of Fe and Zn were recorded with straw compared with the highest values of roots at four rice species; the highest values of Fe, Mn and Zn were obtained at control, and decreased with treated of cadmium. In this concern, Yang *et al.* (1996) stated that, the content of Zn, Fe, Cu, Mn, Ca, and Mg decreased with increasing external Cd levels, and plant species differed. He added that the influxes decreased 35% for Zn, 40% for Fe, 80% for Mn, 40% for Ca, and 75% for Mg in white clover grown with Cd up to 14 µM Cd.

C- Effect of Cd treatments on grain yield and some nutrient contents of rice plant.

Data presented in table 4 show that, the yield of rice grain was highly affected by cadmium treatments; the highest values of grain was recorded at without control and sharply decreased with increasing concentration of treatments. The high values of grain were 0.82 g/plant, obtained at control for Giza 177. While the least value was 0.35 g/plant obtained with 3 mg. l^{-1} cadmium concentration of Giza 178. These results are in agreement with Liu *et al.,* (2008).

Table 4: Effect of Cd treatments on grain yield and their content of some nutrients.

Variety	Treatments of Cd (mg.l^{-1})	D.W. of grain g/plant	Cd (mg/kg. d.w.)	N and K content (%)		Micronutrients (mg/kg. d.w.)		
				N	K	Fe	Mn	Zn
Sakha 106	0	0.76	0.004	0.630	0.600	0.273	0.197	0.243
	1	0.46	0.013	0.560	0.580	0.298	0.170	0.245
	2	0.39	0.012	0.460	0.560	0.207	0.154	0.241
	3	0.38	0.019	0.390	0.570	0.181	0.150	0.213
	Mean	0.497	0.012	0.510	0.577	0.240	0.168	0.236
Sakha 104	0	0.69	0.005	0.670	0.800	0.264	0.225	0.235
	1	0.54	0.011	0.630	0.590	0.221	0.273	0.219
	2	0.35	0.019	0.630	0.510	0.272	0.159	0.241
	3	0.46	0.020	0.390	0.350	0.260	0.114	0.204
	Mean	0.510	0.014	0.580	0.563	0.292	0.193	0.240
Giza 178	0	0.79	0.003	0.600	1.050	0.256	0.189	0.198
	1	0.87	0.018	0.530	1.120	0.236	0.185	0.192
	2	0.67	0.014	0.600	0.870	0.231	0.156	0.179
	3	0.36	0.018	0.510	0.730	0.253	0.142	0.165
	Mean	0.673	0.013	0.560	0.942	0.244	0.168	0.184
Giza 177	0	0.82	0.002	0.49	1.03	0.254	0.192	0.214
	1	0.76	0.006	0.53	0.68	0.237	0.138	0.189
	2	0.51	0.013	0.46	0.74	0.245	0.123	0.187
	3	0.47	0.015	0.39	0.65	0.231	0.117	0.152
	Mean	0.640	0.009	0.466	0775	0.242	0.142	0.186
Mean of Cd treatments	0	0.765	0.004	0.598	0.870	0.262	0.201	0.223
	1	0.656	0.012	0.561	0.742	0.248	0.192	0.212
	2	0.480	0.014	0.537	0.670	0.276	0.148	0.227
	3	0.417	0.018	0.420	0.575	0.231	0.131	0.183
LSD at 5% level	A	0.0024	0.00012	0.0024	010012	n.s	0.00416	0.021
	B	0.0024	0.00012	0.0024	0.0012	n.s	0.00416	0.021
	A×B	0.0048	0.00024	0.0048	0.0024	0.107	0.00832	n.s

While, Zhou *et al.* (2003) found that rice plant height and grain yield were decreased by about 4 to 5 cm and 20 to 30 %, respectively due to the effect of Cd. Also, Muramoto *et al*. (1990) stated that, the grain, shoot and root weights of rice were reduced by 18-28, 17-35 and 27-54 %, respectively at the highest Cd treatment compared to the control.

Concerning the effect of cadmium concentration in growth media on cadmium uptake by rice grain, data show that, the lowest values of cadmium uptake were recorded with grain compared to the highest values of roots and straw at four Varity of rice. In this concern, Paul *et al.* (2010) stated that, the high cadmium content in rice plant might have an adverse effect on growth and yield of the rice plant, and he added, the Cadmium concentrations in rice plants followed: root then, stem more than grain.

The highest value of cadmium content was reached 0.020 mg/kg. at 3 mg.l^{-1} of sakha 104, compared with other treatments and control.

With regard to the effect of cadmium concentration on nitrogen and potassium content of rice grain, data in table 4 show that, the mentioned trend of N and K content of straw were observed for N and K content of rice grain. The highest value was 0.67% at untreated control of sakha 104 Varity for nitrogen; while the highest value was 1.05% which obtained with control of Giza 178 Varity for potassium. Low levels of these elements in food, or marginal nutritional status of the consumer's usual diet may cause increased intestinal absorption and accumulation of Cd Reeves and Chaney, (2001). Also, Liu *et al.* (2006) stated that the Mn uptake and accumulation significantly decreased with increasing Cd ions in nutrient solution in all maize cultivars.

D- Rice tolerant of cadmium

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 apoplastic or sympllastic 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 (Salt *et al*., 1995).

Concerning the four rice verities tolerant to cadmium, data in table 5 reveal that the highest values were 97.50 and 82.99% obtained with 1and 2 mg.l^{-1} cadmium concentration, respectively of Giza 178 Varity; while at 3 mg/l^{-1} the highest value was recorded with Sakha 104 Varity compared to control and other varieties. Generally, at the low cadmium concentration (1 and 2 mg.l^{-1}) in growth media the best values of tolerant were recorded with Giza 178 Varity, followed Giza 177 Varity more than Sakha 106 and 104 variety; while, at the high concentration (3 mg.l^{-1}) the best values of tolerant were recorded with Sakha 104 Varity, followed Giza 178 Varity, then Giza 177 Varity better than Sakha 106 compared to control.

In this concern, Hall (2002) stated that differences in root uptake and shoot accumulation of Cd can 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.

Table 5: Tolerance indexes of rice varieties

Treatments of Cd. mg/l^{-1}	Rice varieties							
	Sakha 106		Sakha 104		Giza 178		Giza 177	
	D.W. g/plant	*R.V.	D.W. g/plant	R.V.	D.W. g/plant	R.V.	D.W. g/plant	R.V.
0	7.97	100	7.49	100	6.82	100	6.77	100
1	6.23	78.16	5.97	79.70	6.65	97.50	5.67	83.75
2	5.12	64.24	4.85	64.75	5.66	82.99	4.65	68.68
3	3.43	43.03	4.20	56.07	3.69	54.10	3.38	49.92

**relative value of plant tolerant.*

Conclusion

The present research concludes that, the highest dry matter (shoot, root and grain yield) were recorded with the low concentration of cadmium. The cadmium uptake and accumulation in plant parts were increased with increasing concentration. Mostly the studied nutrient contents of rice were decreased with increasing cadmium concentration of four rice variety compared with control. The yield of rice grain was highly affected by cadmium treatments. The highest values of cadmium uptake were recorded with roots more than shoots and the lowest values of grain at four varieties of rice plant. Also, this study can be considered as a screening to determine the ability of some Egyptian rice varieties for heavy metals toxicity tolerance such as cadmium.

Sakha 104 and Giza 178 varieties had the highest tolerance to Cd toxicity and they could be used for the development of new rice varieties tolerant to Cd toxicity through rice breeding and improvement programs.

References

Abdel-Latifbn A., 2008. Cadmium Induced Changes in Pigment Content, Ion Uptake, Proline Content and Phosphoenolpyruvate Carboxylase Activity in *Triticum Aestivum* Seedlings. Australian Journal of Basic and Applied Sciences, 2(1): 57-62,

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.

Boominathan R. and P. M. Doran, 2003. Cadmium tolerance and antioxidative defenses in hairy roots of the cadmium hyperaccumulator Thlaspi caerulescens. Biotechnology and Bioengineering 83: 158–167.

Cao, H., J. Chen, J. Zhang, H. Zhang, L. Qiao and Y. Men, 2010. Heavy metals in rice and garden vegetables and their potential health risks to inhabitants in the vicinity of an industrial zone in Jiangsu, China. J Environ Sci ., 22(11): 1792-1799.

Cataldo, D.A., T.R. Garl and R.E. Wildung, 1983. Cadmium uptake kinetics in intact soybean plants. Plant physiol. 73: pp 844-848.

Das P., S. Samantaray and G.R. Rout, 1999. Studies on cadmium toxicity in plants: A review. Environmental Pollution 98: 29–36.

De Maria S., M. Puschenreiter and A. R. Rivelli, 2013. Cadmium accumulation and physiological responseof sunflower plants to Cd during the vegetative growing cycle. Plant Soil Environ. 59(6): 254–261.

Ernst W.H., J.A. Verkleji and H. Schat, 1992. Metal tolerance in plants. Acta Bot Neerl. 41: 229-248.

Farooqi, Z.R., M. Zafar Iqbal, M. Kabir and M. Shafiq, 2009. Toxic Effects of Lead and Cadmium on Germination and Seedling Growth of Albizia Lebbeck (L.) Benth. Pak. J. Bot., 41(1): 27-33.

Guo T.R., G.P. Zhang, M.X. Zhou, F.B. Wu and J.X. Chen, 2007. Influence of aluminum and cadmium stresses on mineral nutrition and root exudates in two barley cultivars. *Pedosphere* 17: 505–512.

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

Hernandez L.E., R. Carpena-Ruiza and A. Garatea, 1996. Alterations in the mineral nutrition of pea seedlings exposed to cadmium. Journal of Plant Nutrition 19: 1581–1598.

Jiang W., D. Liu, and P. Xu, 2009. Cd-induced system of defence in the garlic root meristematic cells. Biologia Plantarum 53: 369–372.

Li L., X. Liu, Y. Guo and E.B. Ma, 2005. Activity of the enzymes of the antioxidative system in cadmium-treated Oxya chinensis (Orthoptera Acridoidae). Environmental Toxicology and Pharmacology. 20: 412–416.

Lidon F. C. and F. S. Henriques, 1991. Limiting step on photosynthesis of rice plant treated with varying copper levels. J. Plant Physiol. 138, 115D118.

Lindberg S. and G. Wingstrand, 1985. Mechanisms for Cd^{2+} inhibition of (K^{+}+Mg^{2+}) ATP ase activity and uptake in roots of sugar beet (Beta vulgaris) Physiol. Plant. 63: 181-6.

Liu D., J. Zou, M. Wang and W. Jiang, 2008. Hexavalent chromium uptake and its effects on mineral uptake, antioxidant defence system and photosynthesis in Amaranthus viridis L. Bioresource Technology 99: 2628–2636.

Liu D., I. Kottke, and D. Adam, 2007. Localization of cadmium in the root cells of Allium cepa by energy dispersive X-ray analysis. Biologia Plantarum 51(2): 363–366.

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(3): 701-709.

Liu D., P. Xu, Q. Meng, J. Zou, J. Gu, and W. Jiang, 2009. Pb/Cu effects on the organization of microtubule cytoskeleton in interphase and mitotic cells of Allium sativum L. Plant Cell Reports 28: 695–702.

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.

Kabata-Pendias A. and H. Pendias, 2001. Trace Elements in Soils and Plants. 3rd Edition, CRC Press, Boca Raton.

Kahle, H., 1993. Response of roots trees to heavy metals. Environ. Exp. Bot., 33: 99-119.

Metwally A, V.I. Safronova, A.A. Belimov and K. J. Dietz, 2005. Genotypic variation of the response to cadmium toxicity in *Pisum sativum* L. *Journal of Experimental Botany* 56: 167–178.

Murakami, M., N. Ae, and S. Ishikawa, 2007. Phyto-extraction of Cadmium by Rice (Oryza sativa L.), soybean (Glycine max (L.) merr.), and Maize (Zea mays L.), Environmental Pollution. 145: 96-103.

Muramoto, S., H. Nishizaki and I. Aoyama, 1990. The critical levels and the maximum metal uptake for wheat and rice plants when applying metal oxides to soil. J. Environ Sci Health, Part B. 25 (2):273-80.

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.

Paul, S. K., C. Sasaki, M. Nobuhiko, T. Yoshimura and N. Kaori, 2010. Influence of percolation pattern on growth and yields of rice plants and uptake of cadmium with soil dressing models. 19th World Congress of Soil Science, Soil Solutions for a Changing World.1 – 6 August 2010, Brisbane, Australia.

Pearson, C. and K. Kirkham, 1981. Water relation of wheat cultivars grown with cadmium. J. Pl. Nutr., 3, 309–318.

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

Qin, R., Y. Jiao, S. Zhang, W. Jiang, and D. Liu, 2010. Effects of aluminum on nucleoli in root tip cells and selected physiological and biochemical characters in Allium cepa var. agrogarum L. BMC Plant Biology 225(10): 1471–1482.

Rascio, N., V. F. Dalla, R. N. La, R. Barbato, C. Pagliano, M. Raviolo, C. Gonnelli and R. Gabbrielli, 2008. Metal accumulation and damage in rice (cv. Vialone nano) seedlings exposed to cadmium. Environmental and Experimental Botany 62: 267–278.

Reeves P. G. and R. L. Chaney, 2001. Mineral nutrients status of female rat's a_ects the absorption and organ distribution of cadmium from sunflower kernels (*Helianthus annuus* L.). *Environ Res*, 85: 215–225.

Rizk A. H., 2010. Influence of cadmium on plant growth and some nutrients content of lettuce plant. J. Soil Sci. and Agric Engineering, Mansoura Univ.,1 (8): 829 – 837.

Rogan, N., T. Serafimovski, M. Dolenec, G. Tasev and T. Dolenec, 2009. Heavy metal contamination of paddy soils and rice (*Oryza sativa* L.) from Kocani field (Macedonia). *Environ Geochem Health*, 31(4): 439-451.

(RRTC) Rice Research and Training Center, 2012. Technical recommendation for Rice Research and Training Center, Agricultural Research Center, Ministry of Agriculture and Land Reclamation.

Salt, D., R. Price, I. Pickering and I. Raskin, 1995. Mechanisms of cadmium mobility and accumulation in Indian mustard. Plant Physiol., 109, 1427–1433.

Sandalio, L., H. Dalurzo, M. Gomez, M. Romero and L. Delrio, 2001. Cadmium-induced Changes in the Growth and Oxidative Metabolism of Pea Plants. J. Exp. Bot., 52: 211-2126.

Sanita di Toppi. L and R. Gabbrielli, 1999. Response to cadmium in higher plants. *Environ. Exp. Bot*., 41: 105-130

Satarug, S., J.R. Baker, S. Urbenjapol, M. Haswell-Elkins, P.E. Reilly, D.J. Williams and M.R. Moore, 2003. A global perspective on cadmium pollution and toxicity in nonoccupationally exposed population. *Toxicol. Lett.*, 137(1- 2): 65-83.

Stone, R., 2008. Food safety-Arsenic and paddy rice: A neglected cancer risk? *Science*, 321(5886): 184-185.

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.

Snedecor, G.W. and W.G. Cochran, 1980. "*Statistical Methods*", 6*th* ed., Iowa state Univ.Press, Ames lowa, USA.

Veselov, D., G. Kudoyarova, M. Symonyan and S. Veselov, 2003. Effect of Cadmium on Ion Uptake, Transpirationand Cytokinin Content in Wheat Seedlings. Bulg. J. Plant Physiol., Special Issue, 353–359.

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

Yang, X., V. C. Baligar, D. C. Martens and R. B. Clark, 1996. Cadmium Effects on Influx and Transport of Mineral Nutrients In Plant Species. Journal of Plant Nutrition, 19(3&4), 643-656.

Yourtchi, M. S. and H. R. Bayat, 2013. Effect of cadmium toxicity on growth, cadmium accumulation and macronutrient content of durum wheat (Dena CV.) Intl J Agri Crop Sci. 6 (15), 1099-1103.

Zhou Q., X. Wang, R. Liang, and Y. Wu, 2003. Effects of Cadmium and Mixed Heavy Metals on Rice Growth in Liaoning, China Soil and Sediment Contamination 12, 851-864.