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COMPARATIVE EFFECT OF ZINC AND CADMIUM ON THE GROWTH CHARACTERS OF WHEAT (*TRETICUM AESTIVUM* L.) PLANT GROWN IN SAND CULTURE

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ABSTRACT

Pot experiments were carried out, in the glasshouse of the Department of Soil and Water Sciences -Faculty of Agriculture -Alexandria University, to investigate the effect of Zn or Cd on the growth performance of wheat plant(Triticum aestivum L, variety Giza 168) grown in sand culture and its contents of photosynthetic pigments. Different concentrations of Zn (as $ZnSO_4$) or Cd (as $CdCl_2$), in half strength nutrient solution as a base solution, were used for irrigation. Wheat plants were collected after 15 and 30 days from planting for measuring growth characters of roots and leaves, and their contents of Zn, Cd, Chl a, Chl b, and carotenes in plant leaves.

The results showed significant increases in both the dry weights of shoots and roots with increasing Zn and significant decreases of both with increasing Cd. The concentrations of Zn and Cd and their uptake were greater in roots than in shoot and increased with plant age. However, the uptake rates of Zn and Cd were higher in shoots than roots which varied for Zn from 10.12 to 19.46 ug Zn/plant per week in shoots and from 4.73 to 11.64 ug Zn/plant per week in roots, and for Cd from 0.120 to 0.270 and from 0.100 to 0.221 ug Cd/plant per week in shoots and roots, respectively.

Roots characters expressed as surface area, volume, length, and radius showed high growth response to Zn while these growth characters were adversely affected by Cd. Also, the leaf surface area (LSA) and net assimilation rate (NAR) increased significantly with increasing Zn and decreased significantly with increasing Cd in the nutrient solution. In additions, the concentrations of Chl a, Chl b and carotenes had significantly increased with added Zn and significantly decreased with added Cd. These results showed that Chl b synthesis was more sensitive to Zn or Cd than Chl a. On the other hand, carotenes synthesis was moderately affected by increasing concentrations of Zn or Cd in plant leaves.

Key words: Wheat plant, Zinc, Cadmium, Photosynthetic Pigments, Relative growth rate.

INTRODUCTION

Zinc is an essential plant nutrient and is involved in several biochemical reactions in plant. Because its availability in Egyption soils is very low and its deficiency is most common in these soils, application of Zn can improve nutritional status of Zn in soil (Rengel, 1999). On the other hand, cadmium is a nonessential nutrient and is highly toxic to plants when occurred in the growth media in high concentrations. It can reach the soil from several sources such as phosphatic fertilizers, sewage sludge and atmospheric fallout. Because of its chemical similarity with Zn, both elements can interact for absorption by plant roots. In general, the rate of Cd or Zn uptake by plant is positively correlated with its available pool at the root surface (Marschner,1990). However, the mechanisms of Cd uptake by plant have not been well known(Cutler and Rains, 1979; Catalado and Wildung, 1978; Haslett et al., 2001; Veselov et al.,2003), while Zn uptake appears to be active(Giordano et al.,1974).

The adverse effects of Cd are due to its interference with several biochemical reactions in plant (Stiborova et al., 1987, and Marschner,1990), such as its role in the reduction in both cell size and intercellular space of plant tissue (Barcelo et al., 1988) and its inhibition effects on synthesis of photosynthesis pigments (Baszynski et al., 1980; Sheoran et al.,1990; Abo – Kassem et al.,1997; Öncel et al.,2000; and Shukla et al.,2003). It has been reported that high Cd and low Zn concentrations in plant leaves caused some types of chlorosis depending on plant species (Kabata – Pendias and Pendias,1992).

The objective of this work, therefore, was to evaluate the comparative effect of Zn and Cd on wheat plant, grown in sand culture, with respect to the response of some growth characters and synthesis of some photosynthetic pigments.

MATERIALS AND METHODS

Sand culture technique (Hewitt,1966) was employed to evaluate the effect of Zn or Cd on the growth performance of wheat(*Triticum aestivum L.*) variety Giza 168.

Experimental Layout

One Kg oven-dried pre-washed sand of 1-2 mm size (Hewitt, 1966) was placed in a plastic pot of 15 cm inside diameter and 12 cm depth. Surface sterilized seeds of wheat (Hewitt, 1966) were germinated in this sand culture and watered with distilled water. After seven days from planting the wheat seedlings were thinned to 10 plants per pot and then irrigated with Zn or Cd solution. The trace element treatments included daily irrigation with 100 ml Half-strength nutrient solution of Hoagland and Arnon (Hewitt,1966), as a base solution containing either Zn as $ZnSO_4.7H_2O$ or Cd as $CdCl_2$. The pH of this solution was adjusted to 7.5 by 0.1M Tris (hydroxy methyl) aminothan buffer according to Hajiboland et al.(2003) with slight modification. The Zn treatments were 0.00, 0.025, 0.050, and 0.100 mg Zn L^{-1} and those of Cd were 0.00, 0.01, 0.02 , and 0.04 mg Cd L^{-1}. Each treatment was repeated in six replicates and the pots were distributed randomly in the glasshouse of the Department of Soil and Water Sciences -Facultly of Agriculture - Alexandria University.

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The whole plants (three replicates from each treatment) were collected after 15 and 30 days from planting, washed with distilled water, separated into roots and shoots and the fresh weight was measured (Hewitt, 1966). Proportion of the fresh plant was preserved for measuring leaves and roots growth parameters, physiological and biochemical components (Hewitt, 1966), while the other proportions were oven-dried at 65^{0}C for 48 hrs, and their weight were measured. The oven - dried plant materials were finely ground using stainless steel mill and stored for chemical analysis (Chapman and Pratt, 1961).

Plant Analysis:

i - Morphological Analysis: The roots length and their volume, radius and surface area were calculated according to Tennant, (1975). In addition, the leaf surface area was measured by Planimeter, and the leaf area ratio (LAR), relative growth rate (RGR), net assimilation rate(NAR) were calculated (Evans,1972) as follows:

(i) - Leaf area ratio (LAR) $cm^2 / g = A_x / TW_x$.

(ii) - Relative growth rate (RGR) $g.g^{-1}.week^{-1}$

$= (\ln TW_2 - \ln TW1) / (T_2 - T_1)$.

(iii) -Net assimilation rate (NAR) $g .cm^{-2} .week^{-1}$ $=(TW_2-TW_1) x (\ln A_2-\ln A_1) /((T_2-T_1) x (A_2-A_1))$.

Where:

T_1 = time1, T2 = time 2, TW_x = total dry weight at T_x, A_x = leaf area at t_x

ii- Chemical Analysis: The oven-dried plant material was wet digested with concentrated HNO_3 and H_2O_2 (Jones,1989), and the concentrations of Zn and Cd were measured by atomic absorption spectrophotometer (Varian,Spectra AA220). In addition, the concentrations of photosynthetic pigments (chlorophyll a and b and carotenens) were determined in fresh plant leaves according to the methods outlined by Horowitz (1975).

The obtained data were statistically analyzed for the least significant difference using PC-SAS software (SAS Institute,1988).

RESULTS AND DISCUSSION

Plant Growth:

Table 1 showed significant increases in the dry weights of shoots and roots of wheat (*Triticum aestivum L.*) plants collected after 15 and 30 days from planting with increasing Zn concentrations. The relative increase of roots dry weight of plants treated with 0.1 mg Zn L^{-1}, was higher than that of shoots (average values of 22 and 45% for 15 and 30 days old roots, and 7 and 30% for 15 and 30 days old shoots, respectively). The values of shoots/roots ratio had decreased from 3.24 and 2.72, for the control plants collected after 15 and 30 day from planting to 2.36 and 2.26 for plants treated with 0.100 mg Zn L^{-1} , respectively. This indicates higher response of roots than shoots to Zn treatments. The stimulating action of Zn in the growth of wheat (*Triticum aestivum L.*) was reported by Marschner (1990), Haslett et al. (2001) and Zhao et al.(2005). On the other hand, increasing Cd concentrations decreased significantly the dry weights of shoots and roots of wheat plants (Table 2). The relative decreases of the dry weights of plants, treated with 0.04 mg Cd L^{-1}, were 8 and 12% for roots and 3 and 5% for shoots of 15 and 30 days old plants, respectively. The values of shoots/roots ratio were increased from 3.24 and 2.51, for the control plants of 15 and30 days old to 4.10 and 2.71for plants treated with 0.04 mg Cd L^{-1} , respectively. This indicates that the roots growth was adversly affected by Cd more than shoots. The growth reduction of shoots and roots, due to Cd increase in the growth medium, was also reported by Keltjens and van Beusichem (1998), Öncel et al. (2000), Zhang et al. (2002), Athar and Ahmad (2002), Shukla et al. (2003) , and Stolt et al. (2003) who showed that the growth of roots was more inhibited by Cd than shoots. Stiborova et al. (1987) reported that this growth reduction could be a consequence of Cd^{2+} interference with several metabolic processes in plant.

Zinc and Cdmium Contents:

Table 1 showed significant increase of Zn concentrations in the shoots and roots of wheat plants, collected after 15 and 30 days from planting, with increasing applied Zn. The Zn concentrations in roots were almost higher than in shoots. The values of Zn shoots/Zn roots ratio were almost less than unity (0.54 and 0.56 in the control and 0.73 and 0.75 in the 0.100 mg Zn L^{-1} treated of 15 and 30 days old plants, respectively). It is also clear that this ratio had increased with increasing both Zn concentrations and plant age which indicates increasing rate of Zn transport from roots to shoots. This points out to the high efficiency of wheat for transporting Zn from roots to shoots with increasing Zn supply. Haslett et al. (2001) found that Zn concentration in shoots has increased with plant age and that the ratio of Zn shoot/ Zn root had increased with increasing Zn treatments. They suggested that Zn transport from roots to shoots was very limited during low Zn-supply which had produced Zn-deficient plants. Zhao et al. (2005) found that Zn concentrations in shoots and roots of wheat plant (*Triticum aestivum L.*) significantly increased with increasing Zn in the nutrient solution.

Table 2 showed significant increase of Cd concentrations in shoots and roots of wheat plants, collected after 15 and 30 days from planting, either with increasing both Cd concentration in the nutrient solution or with plant age. Results also showed that the concentrations of Cd in roots were almost higher than in shoots which indicates that Cd transport from roots to shoots is relatively low. This is evident from the values of Cd shoots/ Cd roots ratio which were higher in the control of 30 days old plants (0.67) than in 30 days old plants treated with 0.04 mg Cd L^{-1} (0.43). However, these ratios in plants collected after 15 days from planting were nearly close. This points out that with increasing both Cd concentrations in the nutrient solution and with plant age, the magnitude of Cd transport from roots to shoots was relatively low and that the highest proportion of absorbed Cd by plant was accumulated in the roots. The high retention of Cd in roots of wheat against translocation to shoots was reported by Hart et al. (1998) and Keltjens and van Beusichem, (1998). Several studies showed that roots of wheat plants had higher Cd concentrations than stems and grains and that the retention of Cd in roots occupied more than 50% of the total Cd in plant at maturity (Zhang et al., 2002., Shukla et al., 2003, and Stolt et al., 2003).

Zinc and Cdmium Uptake:

Figure 1 showed that Zn uptake by shoots was greater than by roots of 15 and 30 days old plant with increasing Zn concentration in the nutrient solution. This is also evident with increasing plant age. In addition, Table 3 showed, on the average, higher Zn uptake rate by shoots (14.71 ug Zn/plant per week) than by roots (8.08 ug Zn/plant per Week). These data revealed high Zn transport from roots to shoots and that higher proportion of plant Zn is accumulated in shoots than roots. On the other hand, Figure2 showed higher Cd uptake by shoots than by roots of 15 and 30 days old plants with increasing Cd concentration in the nutrient solution. The uptake of Cd also had increased with plant age. In addition, Table 3 showed, on the average, higher Cd uptake rate by shoots (0.218 ug Cd/plant per week) than by roots (0.185 ug Cd/plant per week) which indicates that Cd transport from roots to shoots is high relatively.

These data (Tables 1, 2 and 3 and Figs 1 and 2) showed that Zn and Cd concentrations in plant organs had increased with both increasing elements concentration treatments and plant age. The rate of Zn transport from roots to shoots was better than the rate of Cd transport from roots to shoots. This points out that Zn absorbed in roots was easily transported to shoots more than that of Cd.

Root Morphology:

Table 4 showed significant increases in the surface area, volume, length and radius of roots with increasing both Zn concentration and plant age. This is due to the stimulating effect of Zn on the growth of plant cells and consequently plant roots. (Marschner,1990).The relative increases of the surface area, and radius of roots due to Zn treatments were higher in 15 days old plant than 30 days old plant (Figs 3 and 5). This points out to higher response of 15 days old plant to Zn than old of 30 days old plant and that the rates of cell devision and volume increase are greater with younger than older plants. This is evident by calculating the specific surface of roots which were higher in younger plant (average of 339 cm^2/g) than older one (average of 188 cm^2/g). On the other hand, increasing Cd concentrations significantly decreased roots growth characters (Table 5). The relative decreases of roots surface area, and roots radius, due Cd treatments, were higher in 15 days old plant than 30 days old plant (Figs 6 and 8). On the other hand, the relative decreases of roots length were higher for in 30 days old plant than 15 days old plant (Fig 7). Kabata – Pendias and Pendias (1992) and Keltjens and van Beusichem,(1998) found that root length of plants had decreased with increasing Cd concentration in the growth medium. Stiborova et al., (1987) attributed the reduction in roots growth to the interference of Cd with several metabolic processes in plant. Calculating the specific surface of roots showed that younger plant had higher values (average of 357cm^2/g) than older one (average of 262 cm^2/g) which indicate the adverse effects of Cd on cell devision and volume were greater in old plant than young one.

Leaf Morphology:

Table 6 showed significant increases in leaf surface area (LSA) of wheat plant with both increasing Zn concentration and plant age. The relative increases, with 0.1 mg Zn L^{-1} treatment after 15 and 30 days from planting, were 14.7 and 18.6%, respectively. However, leaf area ratio (LAR) was decreased with both Zn increase and plant age. This is due to the increase in plant dry weight with increasing Zn concentration. It is also clear that Zn treatments increased the net assimilation rate in leaves of wheat plant, which is due to the stimulating effect of Zn on the biochemical reactions and consequently growth of plant cells (Marschner,1990). The results also indicated the increase of NAR with increasing Zn concentration. On the other hand, Table 7 showed significant decreases in leaf surface area (LSA) of wheat plant with increasing Cd concentrations, but it was increased with increasing plant age.The relative decreases in LSA of plant treated with 0.04 mg Cd L^{-1} and collected after 15 and 30 days from planting were 10.6 and 14.4%, respectively. This indicates that increasing Cd in the nutrient solution had progressive adverse effect on plant growth and this adverse effect increases with plant age. On the other hand, LAR was increased with increasing Cd concentration which is due to the decrease in dry weight of plant, but it was decreased with increasing plant age. Table 7 also showed decreases of NAR with increasing Cd concentration. The relative decrease of NAR was 50% for plants treated with 0.04mg Cd L^{-1} compared with the control. The data reported by Abo- Kassem et al. (1997) showed significant reduction of NAR with increasing Cd concentration in the nutrient solution.

Table 1 –The mean values of the dry weights and Zn concentrations in shoots and roots of wheat plant collected after 15 and 30 days from planting as infleunced by Zn concentrations.

Zn Conc. mg L^{-1}	Dry weight (g/plant)						Zn Conc. (ug/g D.W.)					
	Shoots		Roots		Shoots/Roots		Shoots		Roots		Zn Shoots/Roots	
	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.
0.000	0.055	0.212	0.017	0.078	1.34	1.48	30.0	45.3	55.7	81.1	0.54	0.56
0.025	0.061	0.267	0.020	0.093	1.37	1.56	87.5	96.7	119.0	130.1	0.74	0.74
0.050	0.067	0.299	0.028	0.127	1.40	1.59	95.8	119.8	131.8	153.3	0.73	0.78
0.100	0.078	0.323	0.033	0.143	1.46	1.60	101.8	141.3	140.2	188.3	0.73	0.75
LSD 0.05 0.01	0.0010 0.0015	0.0233 0.0353	0.0012 0.0017	0.0129 0.0196	---------	---------	3.0359 5.0124	6.7664 10.2592	3.2455 4.9208	7.2788 11.0361	---------	---------

Table 2 –The mean values of the dry weights and Cd concentrations in shoots and roots of wheat plant collected after 15 and 30 days from planting as infleunced by Cd concentrations.

Cd Conc. mg L^{-1}	Dry weight (g/plant)						Cd Conc. (ug/g D.W.)					
	Shoots		Roots		Shoots/Roots		Shoots		Roots		Cd Shoots/Roots	
	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.	15 d.	30 d.
0.00	0.055	0.213	0.017	0.085	3.24	2.51	0.1	0.2	0.2	0.3	0.50	0.67
0.01	0.050	0.192	0.014	0.076	3.57	2.53	0.9	1.5	1.8	3.2	0.50	0.47
0.02	0.047	0.161	0.012	0.067	3.92	2.40	2.1	4.0	4.6	8.7	0.48	0.46
0.04	0.041	0.130	0.010	0.048	4.10	2.71	3.5	5.5	7.1	12.8	0.49	0.43
LSD 0.05 0.01	0.0011 0.0014	0.015 0.023	0.0012 0.0018	0.0094 0.0142	---------	---------	0.0999 0.1515	0.0881 0.1336	0.1153 0.1749	0.0999 0.1515	---------	---------

Table 3 – The uptake rates of Zn and Cd by wheat plant (ug/plant per week) during 15 and 30 days growth period.

Zn Conc. mg L^{-1}	Zn uptake rate		Cd Conc. mg L^{-1}	Cd uptake rate	
	Shoots	Roots		Shoots	Roots
0.025	10.12	4.73	0.01	0.120	0.100
0.050	14.55	7.88	0.02	0.265	0.234
0.100	19.46	11.64	0.04	0.270	0.221

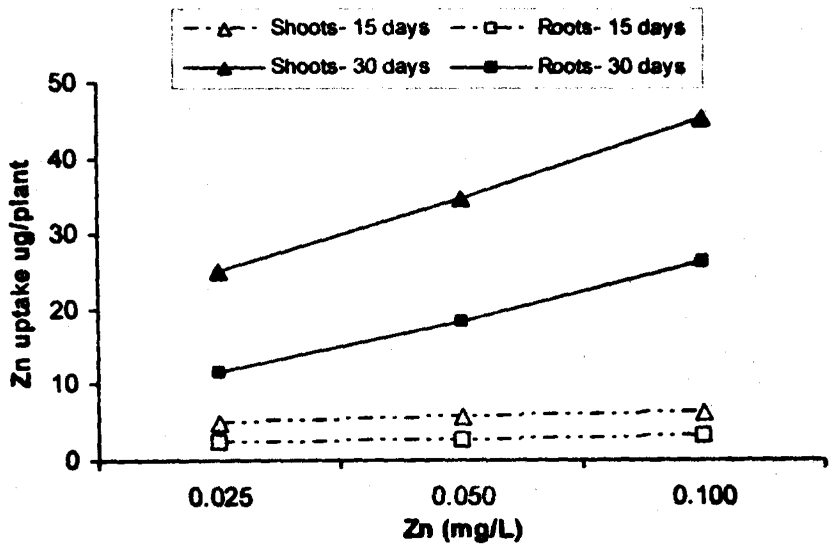

Fig 1- The relation between Zn concentration in the nutrient solution and Zn uptake by shoots and roots of 15 and 30 days old plants.

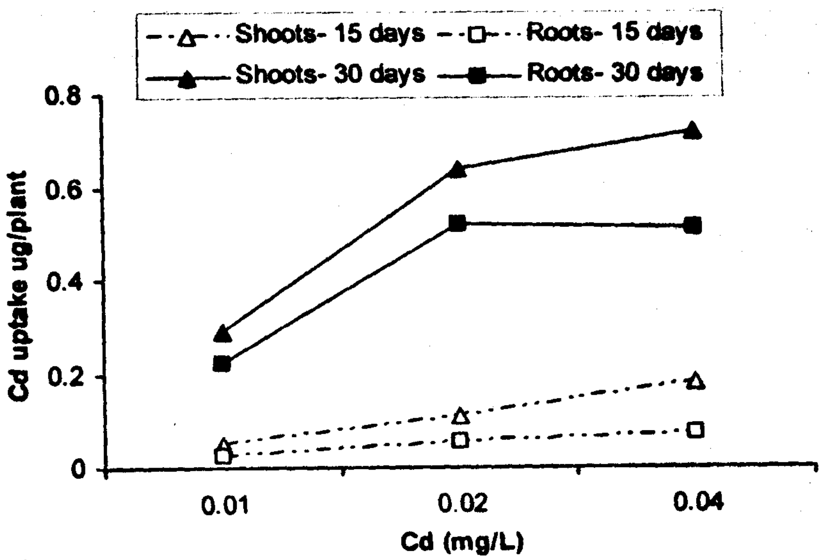

Fig 2- The relation between Cd concentration in the nutrient solution and Cd uptake by shoots and roots of 15 and 30 days old plants.

Table 4 - The surface area (cm^2 / plant), volume (cm^3 / plant), length (cm/plant) and radius (cm/ plant) of roots of wheat plant collected after 15 and 30 days from planting as affected by Zn concentration.

mg Zn L^{-1}	Surface area		Volume		Length		Radius	
	15 d	30 d	15 d	30 d	15 d	30 d	15 d	30 d
0.000	20.0	47.2	0.670	2.01	46.1	88.47	0.069	0.085
0.025	21.4	48.7	0.676	2.11	47.4	90.07	0.072	0.086
0.050	22.6	52.0	0.679	2.30	48.7	94.07	0.074	0.088
0.100	23.9	55.7	0.683	2.51	49.3	96.30	0.077	0.092
LSD 0.05	0.1104	0.1489	0.0017	0.0929	0.4418	1.1317	0.0019	0.0015
0.01	0.1674	0.2258	0.0025	0.1408	0.6698	1.7158	0.0028	0.0023

Table 5 - The surface area (cm^2 / plant), volume (cm^3 / plant), length (cm/plant) and radius (cm/ plant) of roots of wheat plant collected after 15 and 30 days from planting as affected by Cd concentration.

mg Cd L^{-1}	Surface area		Volume		Length		Radius	
	15 d	30 d	15 d	30 d	15 d	30 d	15 d	30 d
0.00	20.0	47.2	0.671	1.99	46.1	88.40	0.069	0.085
0.01	17.6	45.1	0.667	1.86	45.3	86.50	0.062	0.083
0.02	16.3	43.3	0.663	1.76	44.6	84.00	0.058	0.082
0.04	14.9	40.6	0.660	1.68	43.1	80.73	0.055	0.080
LSD 0.05	0.1451	0.1998	0.0015	0.0450	0.1597	1.2543	0.0014	0.0014
0.01	0.2201	0.3029	0.0023	0.0684	0.2421	1.9019	0.0021	0.0021

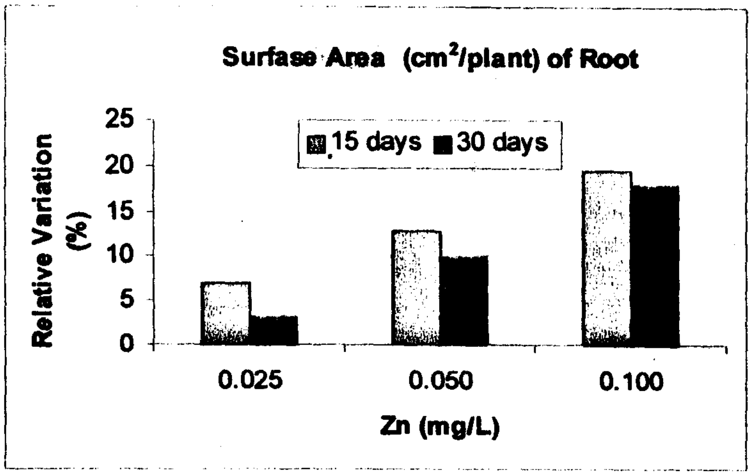

Fig 3: Relation between the Relative variation of root surface area (%) and Zn treatments, mg Zn L^{-1} for wheat plants collected after 15 and 30 days from germination.

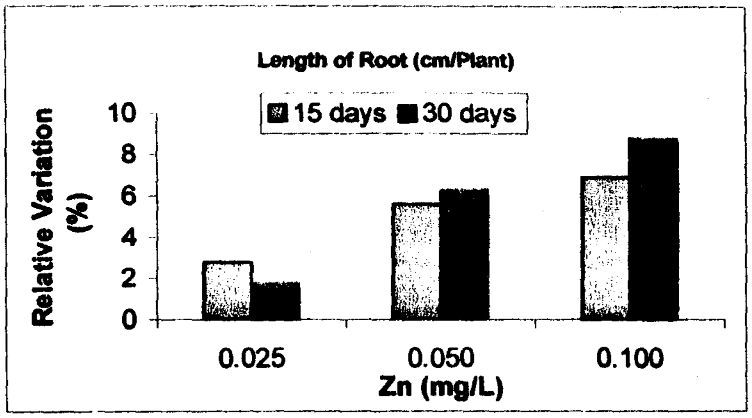

Fig 4 : Relation between the Relative increase of root length (%) and Zn treatments, mg Zn L^{-1} for wheat plants collected after 15 and 30 days from germination.

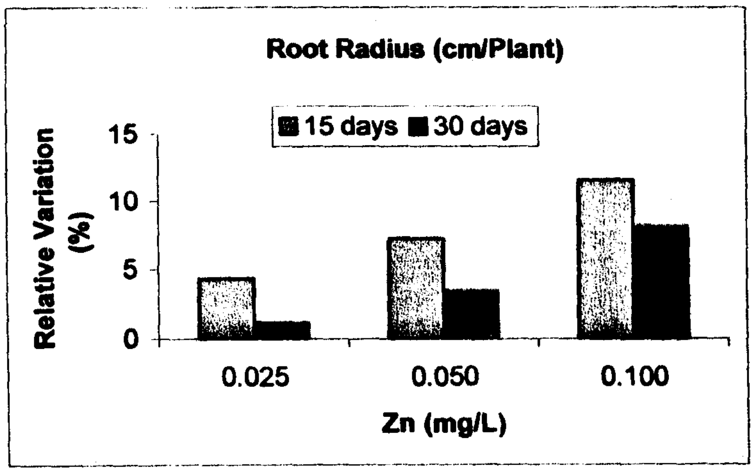

Fig 5: Relation between the Relative increase of root radius (%) and Zn treatments, mg Zn L^{-1} for wheat plants collected after 15 and 30 days from germination.

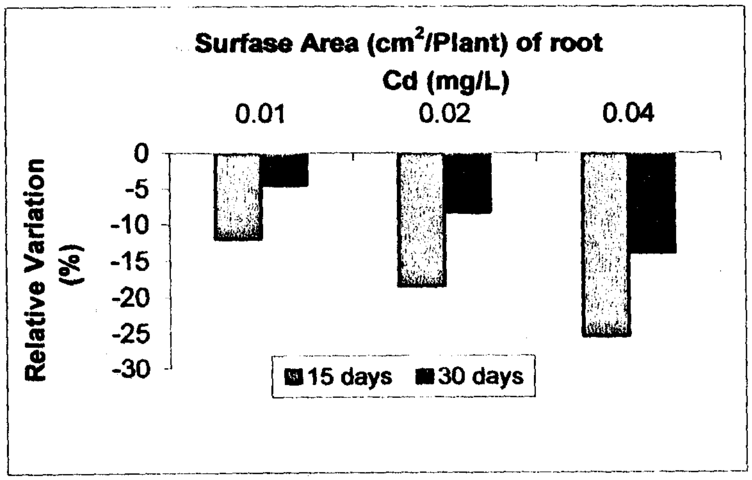

Fig 6: Relation between the Relative variation of root surface area (%) and Cd treatments, mg Cd L^{-1} for wheat plants collected after 15 and 30 days from germination.

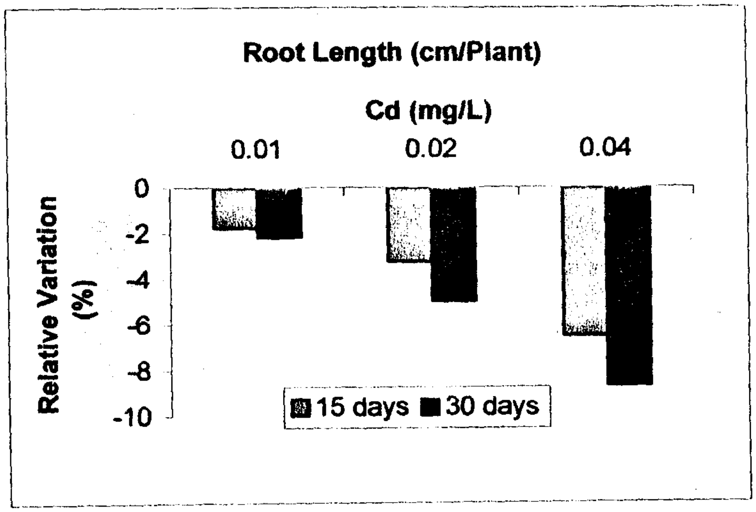

Fig 7: Relation between the Relative variation of root length (%) and Cd treatments, mg Cd L^{-1} for wheat plants collected after 15 and 30 days from germination.

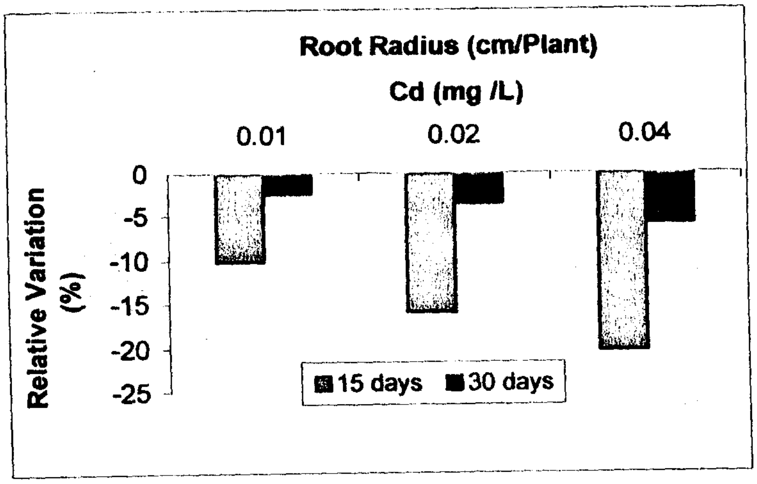

Fig 8: Relation between the Relative variation of root radius (%) and Cd treatments, mg Cd L^{-1} for wheat plants collected after 15 and 30 days from germination.

Table 6- The leaf surface area (LSA), leaf area ratio (LAR) after 15 and 30 days from planting and net assimilation rate in leaves of wheat plant as influenced by Zn concentrations.

Zn conc. mg L^{-1}	LSA (cm^2/ plant)		LAR (cm^2 g^{-1})		NAR mg. cm^{-2}.$week^{-1}$
	15 d	30 d	15 d	30 d	
0.000	14.3	44.80	198.6	154.5	4
0.025	14.8	46.60	197.3	133.1	5
0.050	15.7	48.30	198.7	117.8	6
0.100	16.4	53.13	195.2	115.5	7
LSD 0.05	0.3141	0.1730	-----	-----	-----
0.01	0.4763	0.2623			

Table 7- The leaf surface area (LSA), leaf area ratio (LAR) after 15 and 30 days from planting and net assimilation rate in leaves of wheat plant as influenced by Cd concentrations.

Cd conc. mg L^{-1}	LSA(cm^2/ plant)		LAR(cm^2 g^{-1})		NAR mg. cm^{-2}.$week^{-1}$
	15 d	30 d	15 d	30 d	
0.00	14.2	44.73	197.2	154.2	4
0.01	13.6	42.10	206.1	161.9	4
0.02	13.1	40.73	207.9	185.1	3
0.04	12.7	38.30	211.7	225.3	2
LSD 0.05	0.1665	0.4092	------	------	------
0.01	0.2524	0.6204			

Phtosynthetic Pigments:

Table 8 showed significant increases in the amounts of chlorophyll a and b and carotenes in leaves of wheat plant with increasing both Zn concentrations and plant age. The relative increases in chlorophyll a and b and carotens in leaves of plant treated with 0.1 mg Zn L^{-1} and collected after 15 and 30 days from planting on fresh weight basis were 14.89 and 15.69% for Chl a, 46.67 and 37.50% for Chl b, and 5.31 and 14.50% for carotenes, respectively. This points out that the synthesis of Chl b was higher in younger than in older plant and that of carotenes was higher in older plant than younger plant with the highest Zn treatment.This indicates high sensitivity of Chl b and carotenes to Zn than Chl a at this high Zn treatment. On the other hand, the rate of synthesis of Chl b due to Zn treatments was lower (average of 0.04 mg.g^{-1} F.W per week) than that of Chl a (average of 0.07 mg.g^{-1} F.W.week).This can be noticed with the high values of Chl a /Chl b ratios which had increased with increasing plant age and decreased with increasing Zn treatments. It is also clear that carotenes contents in leaves had increased with increasing both Zn treatments and plant age. The rate of carotenes synthesis had increased from 42.8 mg.g^{-1} F.W per week (the control) to 52.5 mg.g^{-1} F.W per week (0.1 mg Zn L^{-1} treated plant).

Table 9 showed significant decreases in the amounts of Chl a, Chl b and carotines with increasing Cd concentrations, while it increased with plant age. The relative decreases in the amounts of Chl a, Chl b and carotines in leaves of plants collected after 15 and 30 days from planting and treated with 0.04 mg Cd L^{-1} were 28.57 and 22.37% for Chl a, 33.33 and 37.50 % for Chl b, and 11.02 and 10.44% for carotenes. These data indicate the adverse effects of Cd on the synthesis of these three photosynthetic pigments. The leaf chlorosis, in this study, had been observed with older plants rather with younger plants. The values of Chl a/Chl b ratios were increased with increasing Cd treatments which indicates that the synthesis of Chl b was more inhibited in the presence of high Cd concentration than Chl a. Also, the rate of carotenes synthesis had decreased from 42.5 mg.g^{-1} F.W per week in the control plant to 38.5 mg.g^{-1} F.W per week in plant treated with 0.04 mg Cd L^{-1}. The inhibition of photosynthetic processes by high Cd concentration was reported by Baszynski et al.(1980), Sheoran et al. (1990), Pasad, (1995),Abo- Kassem et al. (1997), and (Öncel et al., 2000). It was also found that leaves of wheat plant grown in nutrient solution containing increasing levels of Cd contained significant lower amounts of Chl a, Chl b and carotenes than the control (Shukla et al., 2003).

Table 8- The mean values of chlorophyll and carotene contents (mg. g^{-1} F.W) in whaet plant leaves collected after 15 and 30 days from planting as influenced by Zn concentration.

Zn conc. mg L^{-1}	Chlorophyll a		Chlorophyll b		Chl a/Chl b		carotenes	
	15 d	30 d	15 d	30 d	15 d	30 d	15 d	30 d
0.000	1.41	1.53	0.15	0.16	9.40	9.56	77.2	162.8
0.025	1.45	1.61	0.17	0.18	8.52	8.94	78.0	172.6
0.050	1.55	1.68	0.19	0.20	8.15	8.40	79.3	179.0
0.100	1.62	1.77	0.22	0.22	7.36	8.05	81.3	186.4
LSD 0.05	0.0145	0.0129	0.115	0.0129	-----	-----	0.2424	3.069
0.01	0.0220	0.0196	0.018	0.0196			0.3675	4.623

Table 9- The mean values of chlorophyll and carotene contents (mg. g^{-1} F.W) in whaet plant leaves collected after 15 and 30 days from planting as influenced by Cd concentration.

Cd conc. mg L^{-1}	Chlorophyll a		Chlorophyll b		Chl a/Chl b		carotenes	
	15 d	30 d	15 d	30 d	15 d	30 d	15 d	30 d
0.00	1.40	1.52	0.15	0.16	9.33	9.50	77.1	162.8
0.01	1.23	1.38	0.13	0.14	9.46	9.86	75.4	158.2
0.02	1.05	1.30	0.11	0.13	9.55	10.00	71.4	153.9
0.04	1.00	1.18	0.10	0.10	10.00	11.80	68.6	145.8
LSD 0.05	0.012	0.017	0.010	0.009	-----	-----	0.173	4.110
0.01	0.018	0.025	0.015	0.014			0.262	5.231

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الملخص العربي

تأثير الزنك و الكادميوم على خصائص نمو نبات القمح النامي في مزرعة رملية

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لدراسة تأثير الزنك و الكادميوم على نمو نبات القمح صنف جيزة ١٦٨ النامي في مزرعة رملية و كذلك محتواه من صبغات البناء الضوئي المختلفة مثل كلورفيل ا و ب و كاروتين. قد تم اجراء التجارب في صوبة قسم الأراضي و المياه كلية الزراعة جامعة الإسكندرية و استخدام الري تركيزات مختلفة من الزنك (كبريتات الزنك) و الكادميوم (كلوريد الكادميوم) في محلول مغذى(٠,٥ هوجلند). بعد ١٥ و ٣٠ يوم من الإنبات تم تجميع نباتات القمح لدراسة خصائص النمو في الجذور والأوراق ومحتواه من الزنك و الكادميوم و كلورفيل ا و ب و كاروتين في الأوراق.

أوضحت النتائج المتحصل عليها زيادة معنوية في الوزن الجاف للمجموع الخضري و الجذري مع زيادة الزنك في المحلول المغذى. و أيضا أوضحت النتائج انخفاض معنوي لنفس الخصائص مع زيادة الكادميوم في المحلول المغذى. و كان امتصاص الزنك او الكادميوم وتركيزهما اكبر في المجموع الجذري اكثر من المجموع الخضري و مع زيادة عمر النبات مع أن معدل امتصاص الزنك والكادميوم اكبر في المجموع الخضري عن الجذري. كانت الزيادة في المجموع الخضري بعد ١٥ يوم من الإنبات (٣,٩٣ إلى ١٩,٤٦ ميكروجرام زنك/نبات/الأسبوع) في المجموع الجذري بعد ١٥ يوم (٢,٣١ إلى ١١,٦٤ ميكروجرام زنك/نبات/الأسبوع).والنتائج بالنسبة للكادميوم في المجموع الخضري و الجذري (٠,٠١٥ إلى ٠,٢٧٠ & ٠,٠١١ إلي ٠,٢٢١ ميكروجرام كادميوم/نبات.الأسبوع) على الترتيب.

أوضحت النتائج أيضا زيادة معنوية في مساحة سطح الجذور و حجمها و طولها ونصف قطرها مع زيادة الزنك و انخفاض معنوي مع زيادة الكادميوم.كلما زادت الصبغات المختلفة زادت معنويا مع زيادة الزنك وقلت معنويا مع زيادة الكادميوم. هذه النتائج أوضحت أن تخليق الكلورفيل ب اكثر حساسية لتركيز الزنك او الكادميوم في أوراق النبات اكثر من كلورفيل ا و لكن الكاروتين تأثر بمقدار معتدل بإضافة الزنك او الكادميوم.