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ALLEVIATION OF THE DELETERIOUS EFFECTS OF CADMIUM POLLUTION ON WHEAT PLANTS BY BIOFERTILIZER (HALEX 2) OR GARLIC EXTRACT

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ABSTRACT: *Two pot experiments were carried out during the two seasons of 2003/2004 and 2004/2005 in order to study the effect of cadmium pollution treatments (0, 75, 150 and 300 mg/l), the application of biofertilizer (Halex 2) or garlic extract and their interaction on vegetative growth characters, chemical composition, yield and its attributes as well as grain quality of wheat (Triticum aestivum L.) plants. The obtained results indicated that cadmium treatments negatively affected plant growth characters expressed as plant height, root length, number of tillers, number of leaves, leaf area as well as fresh and dry weight of roots and shoots, especially at high cadmium levels (150 and 300 mg/l). Photosynthetic pigments (chl. a, chl. b, chl. a+b and carotenoids), total soluble sugars, total carbohydrates, total free amino acids and total protein concentrations were sharply decreased by increasing cadmium levels. The enzymatic activities of peroxidase and phenoloxidase were significantly depressed in wheat polluted plants. On the other hand, the accumulation of proline in the analyzed leaves significantly increased following the increase in cadmium levels. The concentration of minerals (N, P and K^+) was negatively correlated with increased cadmium levels in the growth medium, in this regard, the tested organs (leaves, roots, stems and grains) showed different responses to cadmium pollution. The endogenous cadmium concentration increased as a result of increases in cadmium rates. This increase was more pronounced in roots than in leaves, stems and grains of polluted wheat plants. Yield and its attributes, represented by spikes number and weight/plant, spike length, spikeletes number/spike, grains number and weight/spike, grain yield/plant, 1000 grains weight and straw yield/plant as well as grain quality expressed as total carbohydrates concentration were significantly reduced in response to cadmium pollution stress. The inoculation with biofertilizer (Halex 2) or the application of garlic extract exerted significant increase in most tested parameters compared with untreated plants. Meanwhile, these natural substances decreased the accumulation of proline in leaves and the concentration of cadmium in all tested organs. The interactive effects of cadmium pollution treatments and the usage of natural substances alleviated the deleterious effects of cadmium treatments and improved plant growth, chemical composition, yield and its components as well as grain quality of wheat plants.*

Key words: *Wheat plants, cadmium, growth, leaf area, heavy metal, garlic extract, proline, biofertilizer, yield.*

INTRODUCTION

During the last decade, the toxicity of heavy metals to plants has drawn the attention of many environmental scientists (Prasad, 1995). Environmental pollution with heavy metals has increased dramatically since the onsite of the industrial revolution (Begonia *et al.*, 1998). Toxic heavy metal contamination of soil and ground water poses a major environmental problem and human health hazards as they enter the food chain in their absorption and translocation (Wagner, 1993).

There are several sources of heavy metal in the environment, which are natural in some instances or due to human activity. Many areas show higher levels of different heavy metals as a result of commercial fertilizer, utilization of sewage (water and sludge) and animal wastes as agricultural fertilizer, pesticides, herbicides, composts contaminated harbor, auto emission, metal smelting and mining as well as industrial activities such as manufacture of batteries, plastics and automobiles (Prasad, 1995; Aboulroos *et al.*, 1996 and El-Ghinbihi, 2000).

Moreover, phosphate fertilizers are a main source of metal contamination in modern agriculture, which contain discrete amounts of heavy metals especially cadmium impurities (Passarossa *et al.*, 1993). Higher level of cadmium (500 mg/kg) can be found in rock phosphate used for the manufacture of P-fertilizers (Alloway, 1995).

Cadmium is of particular concern to human health as it is concentrated in many cereals, vegetables and fruits. It is recognized as one of the most hazardous elements which, is not essential for plant growth, since, it is known to be easily taken up by plants and translocated within the plants (Kabata-Pendias and Pendias, 1992). Cadmium causes a number of toxic symptoms in plants, e. g. growth reduction, inhibition of photosynthesis, induction and inhibition of enzymes, altered stomatal action, efflux of cations and generation of free radicals (Prasad, 1995). Cadmium is an effective inhibitor of plant growth expressed as severe root growth inhibition. Leaves showed evidence of toxicity and senescence (increased ethylene content and decreased cytokinins and polyamine) with concomitrant metabolic breakdown (Prasad, 1995). The inhibitory effect of cadmium on Photosynthesis is due to its negative effect on net photosynthesis by increasing stomatal and mesophyll resistance to CO_2 uptake, inhibition of stomatal opening, photosynthetic CO_2 fixation of chloroplast, PS II electron flow in chloroplasts and photophosphorylation (Greger *et al.*, 1994). Cadmium exerts its toxicity through membrance damage and inactivation of enzymes, possibly through reaction with –SH-group of proteins (Fuhrer, 1982). The negative effects of cadmium on wheat growth, development and chemical composition were observed by Keltjens and Van Beusichem (1998); Nagoor and Vyas (1998) and Shenker *et al.* (2001).

Beneficial effects of rhizosphere bacteria (*Azotobacter* spp., *Azospirillum* spp. and *Pseudomonas* spp.) have often been based on increased plant growth, faster seed germination, better seedling emergence and increased plant yield. Thus, these bacteria are now called Plant Growth Promoting Rhizobacteria (PGPR) (Kloepper *et al.*, 1988). The stimulatory effects of microorganisms may result from production of phytohormones (Noel *et al.*, 1996), enhancement of availability of some minerals, stimulation of disease-resistance mechanism, liberation of antibiotic substances, induce cytokinins synthesis and facilitate uptake and/or translocation of these growth regulators in plants (Lazarovits and Nowak, 1997). Many *Azospirillum* spp. produce several plant hormones such as indole acetic acid, isobutyric acid and cytokinins in liquid culture (Omay *et al.*, 1993). It is firmly established that the hormonal effects are the main mechanism by which *Azospirillum* enhances plant growth. Theses hormones were found to reverse the adverse effect of stress conditions (Strack and Karwowska, 1978). The importance of biofertilizer inoculation for increasing plant resistance to stress conditions was observed in wheat by Alvarez *et al.* (1996) and Creus *et al.* (1997) and in maize plants by Hamdia and El-Komy (1998). Thus, bacterial activity appears to lessen stress effects.

Recently, considerable attention has been given to reduce pollutants and chemicals in the edible parts of plants that result from using chemical fertilizers and pesticides for increasing yield and pest control. Many natural substances found in the environment are well known as regulators of the growth and development of higher plants. Extracts from some plant species such as garlic contain many growth substances and essential requirements needed for the vegetative and reproductive growth of different plants. Garlic extract is rich in phytohormones such as auxins, amino acids, some inhibitors of an antibiotic nature, allicin, organic sulphur, organic iodine, garllicin, nicotinamide, enzymatic allinase, various ferments and vitamins such as A and B (Lautie and Passebecq, 1979; Helmy, 1992 and El-Desouky *et al.*, 1998). Furthermore, these extracts can protect plants against heavy metal pollution stress. Garlic extract can alleviate the inhibitory effects of heavy metals on plant growth and development. The biological activities of garlic extract are attributed to its sulphur-rich compound (disulfide), in particular allicin that has been found to play a role in the inhibition of chemically induced cytotoxicity and modulate the activity of several metabolizing enzymes (Hassan, 2004). Disulfide may be an effective antioxidant candidate and may therefore play a significant role in the defense against lipid peroxidation (Grudzinski *et al.*, 2001). Ajoene is a natural garlic derived compound produced most efficiently from pure allicin, it is a known inhibitor of glutathione reduction (Ibert *et al.*, 1990).

Therefore, the objective of the present investigation is to evaluate the effect of cadmium pollutant, the application of biofertilizer or garlic extract and their interaction on growth parameters, chemical composition, yield and its attributes as well as grain quality of wheat plants, in an attempt to overcome the negative effects of heavy metal stress on studied characters.

MATERIALS AND METHODS

Two pot experiments were conducted at the Experimental Farm, Faculty of Agriculture, Minufiya University, Shibin El-Kom during the winter seasons of 2003/2004 and 2004/2005 to investigate the effect of cadmium pollution, application of biofertilizer or garlic extract and their interaction on growth characters, chemical parameters, yield and its components as well as grain quality of wheat plants.

Grains of wheat (*Triticum aestivum* L.) cultivar Giza 168 were obtained from the Agricultural Research Center, Cairo, Egypt. Ten grains were sown on December 3rd and 2nd in the first and second seasons, respectively, in plastic pots 30 cm inner diameter and 30 cm depth, filled with 7 kg air dried soil. Ten days after sowing, the seedlings were thinned to five uniformed plants in each pot.

Cadmium sulphate (3 $CdSO_4$. 8 H_2O) was used as a heavy metal pollutant and was added to the irrigation water 7 weeks after sowing at concentrations of 75, 150 and 300 mg/l besides tap water as control.

Biofertilizer (Halex 2), contains a mixture of growth promoting N-fixing bacteria of genera *Azospirillum*, *Azotobacter* and *Klebsiella*, which was kindly supplied by Biofertilization Unit, Plant Pathology Dept., Alexandria University. It was added in irrigation water 8 weeks after sowing at a rate of 1 g/pot and was repeated one week later.

Garlic extract was prepared as watery extract from fresh mature garlic cloves according to the method described by El-Desouky *et al.* (1998) and applied to irrigated water after 8 weeks from sowing at a rate of 250 mg/1 liter and was repeated one week later.

Each experiment included 12 treatments, which were all possible combination of four cadmium treatments and three biofertilizer or garlic extract application. A split-plot design in randomized complete blocks, with five replications was used. Four cadmium (Cd) concentrations (0, 75, 150 and 300 mg/l) were tested and considered as the main plots. Three biofertilizer (Bio) or garlic extract (Gr) treatments (control, Bio and Gr) were applied and considered as the sub-plots and were randomly assigned within each main plot.

Soil used in the present experiments was sandy clay loam, the texture and certain properties of the experimental soil were analyzed according to Page *et al.* (1982), furthermore, the soil was analyzed for cadmium by atomic absorption spectrophotometer in an ammonium acetate extract following the method described by Jackson (1956). The obtained data are presented in Table (1).

Table (1): Physical and chemical properties of the used soil.

Particle Size	Value
Sand %	45
Silt %	15.2
Clay %	39.8
Soil texture	Sand clay
EC (dsm-1)	1.13
PH	7.5
Soluble cations (meq/l)	
Ca^{2+}	4.25
Mg^{2+}	3.1
Na^{+}	4.2
K^{+}	0.96
Cd^{2+} (mg/l)	0.018
Soluble anions (meq/l)	
HCO^{-}_{3}	2.58
Cl^{-}	6.0

Each pot received 1.68 g P_2O_5 as calcium supperphosphate (15.5% P_2O_5), before sowing, N and K were applied in the form of ammonium nitrate (33% N) and potassium sulphate (48% K_2O) at levels of 1.36 g N/pot and 0.81 g K_2O/pot, respectively, which were added in two equal amounts during the growth period. Moisture in the soil was kept at 65% of the total water holding capacity of the soil during the experimental period. The other agricultural practices were done according to the recommend methods for wheat crop.

After 80 days from sowing (2 weeks after the second application of biofertilizer or garlic extract) four plants were randomly selected from each treatment and the following data were recorded:

1- Growth analysis

In each plant sample, plant height (cm), root length (cm), number of tillers/plant, number of leaves/plant, leaf area (cm^2/plant) using the dry weight method according to Aase (1978), as well as fresh and dry weight of roots and shoots (dried at 70°C for 72 hrs.), g/plant were recorded.

2- Chemical analysis:

a- Photosynthetic pigments were extracted from fresh leaves by acetone 85% and determined according to Wettestein (1957), then calculated as mg/g dry weight.

b- Total soluble sugars and total carbohydrates in dry leaves were estimated colorimetrically by phenol sulfuric acid method of Dubois *et al.* (1956).

c- Total free amino acids in dried leaves, was determined using the method of Rosen (1957).

d- Peroxidase activity in O. D./g fresh weight after 2 min. was measured in wheat fresh leaves using the method described by Fehrman and Dimond (1967).

e- Phenoloxidase activity in O. D./g fresh weight after 45 min. was determined in the fresh leaves by the method of Broesh (1954).

f- Free proline in fresh leaf samples was extracted by the method described by Bates *et al.* (1973).

g- Total nitrogen concentration in dry leaves, stems and roots was estimated using micro-kjeldahl method according to Ling (1963).

h- Phosphorus and potassium were determined in dried leaves, stems and roots following the method of Chapman and Pratt (1961).

i- Cadmium was measured in dry leaves, stems and roots by using atomic absorption spectrophotometer according to Cottenie *et al.* (1982).

j- The total protein concentration was calculated by multiplication of total N in leaves, stems and roots by 5.5.

3- Yield and its Attributes

At harvest time (120 days after sowing), spikes number and weight (g)/plant, spike length (cm), spikeletes number/spike, grains number and weight (g)/spike, grain yield/plant (g), weight of 1000 grains (g) and straw yield/plant (g) were recorded. Total nitrogen, phosphorus, potassium, cadmium and protein concentrations were determined in dry grains as above mentioned for dry leaves.

4- Grain Quality

Total carbohydrates concentration in dried grains was determined as above mentioned for dry leaves.

All collected data of both seasons were subjected to statistical analysis using Costat Software (1985). Treatment means were compared based on the revised L. S. D. test at 0.05 level (Snedecor and Cochran, 1981).

RESULTS AND DISCUSSION

1-Vegetative Growth Characters

Data presented in Table (2) show that plant height, root length and number of tillers were markedly decreased as a result of treating wheat plants with different cadmium levels (75, 150 and 300 mg/l). The most negative effect was obtained under 300 mg/l cadmium which inhibited the height of plants by 25.95% and 28.83%, the root length by 39.5% and 55.56% and the number of tillers by 66.67% and 58.14% in the first and second seasons, respectively. In this concern, Prasad (1995) observed that cell expansion growth and whole plant growth is drastically inhibited by Cd toxicity. This inhibition of cell expansion might also be due to the direct or indirect effects of Cd on auxin metabolism or auxin carriers. The obtained results are in agreement with those obtained by Keltjens and Van Beusichem (1998) who reported that root length of wheat and maize plants decreased with increasing Cd concentration.

Moreover, the number of leaves and leaf area were significantly inhibited as a result of cadmium treatments (Tables, 2 & 3). The highest reduction in this respect was observed under higher cadmium concentration (300 mg/l) and reached about 43.54% for number of leaves and 45.41% for leaf area, during the first season. It could be noticed that the reduction in leaf area was mainly due to the decrease in the number of leaves. Furthermore, in Cd treated plants, the decrease in leaf area was not only due to reduced cell size, but also due to decreased intercellular spaces (Prasad, 1995).

As seen in Table (3) increasing cadmium concentration in root media up to 300 mg/l significantly reduced fresh and dry weight of roots and shoots. The maximum reduction was observed under 300 mg/l and reached to 79.83%, 59.92%, 81.25% and 74.66% for fresh weight of roots and shoots as well as dry weight of roots and shoots, respectively. The second season showed the same trend. Similar results were observed by Hernandez *et al.* (1997) on pea; Ghonem *et al.* (1997) on maize; Keltjens and Van Beusichem (1998) on wheat and maize as well as Shenker *et al.* (2001) on wheat and barley who mentioned that, roots and shoots fresh and dry weight significantly decreased with increasing Cd concentration. Root dry weight decreased with raising Cd levels, this may be attributed to the disturbance of enzyme activity which resulted from the phytotoxic effects of the high content of Cd in corn plants as a result of its accumulation (Youssef *et al.*, 1995).

Table (2): Effect of cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction on some growth characters of wheat plants during 2003/2004 and 2004/2005 seasons after 80 days from sowing.

Treatments: Cd levels mg/l	Treatments: Bio or Gr	Plant height (cm): First Season	Plant height (cm): Second Season	Root length (cm): First Season	Root length (cm): Second Season	Number of tillers /plant: First Season	Number of tillers /plant: Second Season	Number of leaves/plant: First Season	Number of leaves/plant: Second Season
0		70.76 a	69.21 a	13.03 a	17.64 a	3.0 a	3.44 a	9.44 a	11.89 a
75		66.12 a	62.44 b	11.16 a	15.48 b	2.33 b	2.56 b	8.11 b	10.0 b
150		61.30 b	55.84 c	8.79 b	13.19 c	1.67 c	2.33 b	6.67 c	8.22 c
300		52.40 c	49.26 d	5.79 c	10.67 d	1.0 d	1.44 c	5.33 d	6.34 d
	Control	57.82 b	53.68 c	7.76 c	12.52 b	1.42 c	1.92 b	5.42 c	6.75 c
	Bio	63.45 a	58.90 b	9.82 b	14.44 a	1.92 b	2.42 b	7.67 b	9.17 b
	Gr	66.67 a	64.99 a	11.5 a	15.78 a	2.67 a	3.0 a	9.08 a	11.42 a
0	Control	66.33 abc	65.57abc	11.17bcd	15.8 bcd	2.33bcd	3.0 abc	7.0 cde	9.33 cd
	Bio	71.77 a	67.97ab	13.10 ab	17.53 ab	2.67 bc	3.33 ab	10.33ab	12.33 ab
	Gr	74.17 a	74.10 a	14.83 a	19.60 a	4.00 a	4.0 a	11.00 a	14.00 a
75	Control	61.17bcde	56.53 cde	10.07bcd	14.13cdef	1.67 cde	2.00cdef	6.00defg	7.33 de
	Bio	67.90 ab	62.37 bcd	11.07bcd	15.80bcd	2.33bcd	2.67 bcd	8.00 cd	10.67 bc
	Gr	69.30 ab	68.43 ab	12.33abc	16.50 bc	3.00 b	3.00 abc	10.33 ab	12.00 ab
150	Control	56.77 de	48.07 ef	6.20 ef	11.57 f	1.00 e	1.67 def	4.67 fg	5.67 ef
	Bio	61.80 bcd	56.17 cde	9.0 cde	13.30 def	1.67 cde	2.33bcde	7.0 cde	8.00 de
	Gr	65.33abcd	63.27abcd	11.17bcd	14.7 bcde	2.33bcd	3.0 abc	8.33 bc	11.00 bc
300	Control	47.0 f	44.53 f	3.6 f	8.57 g	0.67 e	1.0 f	4.0 g	4.67 f
	Bio	52.33 ef	49.07 ef	6.1 ef	11.13 fg	1.0 e	1.33 ef	5.33 efg	5.67 ef
	Gr	57.87cde	54.17def	7.67 de	12.30 ef	1.33 de	2.0cdef	6.67 cdef	8.67 cd

Values marked with same alphabetical letter (s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

Table (3): Effect of cadmium levels, application of biofertilizer or garlic extract and their interaction on some growth characters of wheat plants during 2003/2004 and 2004/2005 seasons after 80 days from sowing.

Treatments		Leaf area (cm^2)/plant		Root fresh weight (g)/plant		Shoot fresh weight (g)/plant		Root dry weight (g)/plant		Shoot dry weight (g)/plant	
Cd levels mg/l	Bio or Gr	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		160.66 a	157.53 a	1.19 a	1.82 a	4.99 a	7.20 a	0.64 a	0.72 a	2.92 a	2.53 a
75		131.02 b	122.61 b	0.72 b	1.30 b	3.70 ab	5.50 b	0.41 b	0.50 b	1.98 b	2.13 ab
150		113.28 c	92.36 c	0.60 b	0.98 c	2.73 bc	4.22 bc	0.20 c	0.37 c	1.36 bc	1.76 ab
300		87.71 d	70.19 d	0.24 c	0.67 d	2.0 c	3.08 c	0.12 c	0.24 d	0.74 c	1.35 b
	Control	76.01 c	62.26 c	0.27 c	0.91 c	2.23 b	3.57 c	0.13 c	0.34 c	1.06 c	1.45 b
	Bio	115.08 b	117.46 b	0.66 b	1.21 b	3.50 a	5.01 b	0.31 b	0.46 b	1.73 b	1.98 ab
	Gr	178.41 a	152.29 a	1.14 a	1.47 a	4.34 a	6.43 a	0.58 a	0.58 a	2.46 a	2.40 a
0	Control	90.59 e	79.48 f	0.45 bcde	1.20 cde	3.49 abcde	4.99 bcde	0.22 cd	0.55 bcd	1.74 bcd	1.98 ab
	Bio	127.4 cd	163.33 b	0.76 bcde	1.87 b	5.53 ab	7.34 ab	0.48 bc	0.74 ab	2.68 b	2.57 ab
	Gr	264.0 a	229.78 a	2.36 a	2.40 a	5.95 a	9.26 a	1.22 a	0.88 a	4.34 a	3.03 a
75	Control	85.80 e	68.27 gh	0.25 de	1.16 cde	2.52 cde	4.38 bcde	0.16 cd	0.38 def	1.38 bcd	1.53 ab
	Bio	127.60 cd	130.79 c	0.89 bc	1.26 cd	3.91 abcd	5.43 bcd	0.45 bcd	0.46 cde	1.96 bc	2.29 ab
	Gr	179.67 b	168.77 b	1.02 b	1.49 bc	4.66 abc	6.69 abc	0.62 b	0.66 abc	2.59 b	2.58 ab
150	Control	81.48 e	59.89 h	0.21 de	0.77 efg	1.76 de	2.89 de	0.08 cd	0.26 ef	0.70 cd	1.29 ab
	Bio	115.50 d	99.35 e	0.77 bcde	0.99 def	2.70 cde	4.09 cde	0.20 cd	0.38 def	1.47 bcd	1.68 ab
	Gr	142.87 c	117.85 d	0.83 bcd	1.19 cde	3.72 abcd	5.69 bcd	0.32 bcd	0.47 cde	1.90 bcd	2.30 ab
300	Control	46.18 f	41.41 i	0.17 e	0.50 g	1.14 e	2.01 e	0.07 d	0.17 f	0.41 d	1.01 b
	Bio	89.83 e	76.38 fg	0.23 de	0.70 fg	1.85 de	3.16 de	0.12 cd	0.25 ef	0.80 cd	1.36 ab
	Gr	127.11 cd	92.77 e	0.33 cde	0.81 efg	3.01 bcde	4.06 cde	0.16 cd	0.31 def	1.00 cd	1.67 ab

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

Concerning the effect of biofertlizer (Halex 2) or garlic extract on wheat vegetative growth characters, data in Tables (2 & 3) indicate that growth characters significantly increased after the application of these natural substances. The application of garlic extract gave maximum mean values for all growth characters under study followed by Halex 2 compared with the control plants. In this regard, El-Desouky *et al.* (1998) showed that application of garlic extract exhibited high significant increase in size of root system, stem length and total dry weight of squash plants. The positive effects of garlic extract could be attributed to the significant increase of endogenous auxins, cytokinins, vitamins, amino acids, riboflavin and ascorbic acid that are already present in the extract (Helmy,1992). Moreover, Saubidet and Barneix (1998) found that the inoculation of wheat plants with *Azospirillum brasilense* stimulated root and shoot growth. Barakat and Gabr (1998) reported that Halex 2 significantly increased plant height, number of leaves, leaf area as well as fresh and dry weight of shoots and roots of tomato plants. The improving effect of *Azospirillum* on plant growth may be due to the fact that this boifertilizer produces several plant hormones such as IAA, IBA and cytokinins and/or improving the availability and acquisition of nutrients, which promote plant growth (Omay *et al.*, 1993).

Regarding the interaction between cadmium treatments and the application of biofertilizer or garlic extract, data in Tables (2& 3) show that Halex 2 or garlic extract treatments positively correlated with all studied growth characters. These treatments seemed to inhibit the negative effects of cadmium pollution and improved plant growth characters, especially under higher cadmium level (300 mg/l). The best results in this concern were obtained from the application of garlic extract followed by biofertilizer compared with untreated plants.

It could be noticed that biofertilizer or garlic extract alleviated the deleterious effect of cadmium pollution in wheat plants. The effect of these substances was much more pronounced at relatively higher concentrations of cadmium. In this concern, results in Tables (2 & 3) reveal that the increase in growth parameters, resulted from the application of biofertilizer or garlic extract, was higher at 300 mg/l cadmium than 75 or 150 mg/l cadmium. These results are in agreement with those observed by Alvarez *et al.* (1996) who mentioned that *Azospirillum brasilense* increased coleoptile speed of growth when wheat seedlings are exposed to water stress. Furthermore, Creus *et al.* (1997) found that the relative elongation rate of shoots, fresh and dry weight of shoots were increased by the inoculation of wheat seedlings with *Azospirillum brasilense* under salt and water stress. The positive effect of garlic extract on wheat growth rate under Cd pollution, which was observed in this study may be attributed to its biological activities due to an allicin compound, which played a role in the inhibition of cytotoxic chemicals and modulated the activity of several metabolizing enzymes (Hassan, 2004), which increased the capacity of wheat plants to tolerate the attack of free radicals generated by cadmium pollution and made them grow better than untreated plants.

2- Chemical Composition

a- Photosynthetic Pigments

Results recorded in Table (4) indicate that chl. a, chl. b, chl. a+b and carotenoids were significantly decreased in Cd treated wheat leaves. The application of higher cadmium level (300 mg/l) reduced chl. a by 58.47% and 54.7%, chl. b by 61.46% and 55.14%, chl. a+b by 59.23% and 54.83% as well as carotenoids by 62.92% and 62.33%, in the first and second seasons, respectively. The decrease in chlorophyll and carotenoids concentrations appears to be one of the first visible biomarkers of cadmium toxicity. The mechanisms of cadmium toxicity on photosynthetic pigments were attributed to inhibiting the biosynthesis of the aminolevulinic acid (ALA), a precursor of chlorophyll (Thomas and Singh, 1996) and/or enhancing the activity of chlorophyllase and chlorophyll degradation (Abdel-Basset *et al.*, 1995). The obtained results are in agreement with those observed by Skorzynska and Basznski (1993) who reported that a significant reduction (73%) in the leaf chlorophyll content was observed with increasing Cd concentration. Furthermore, Gil *et al.* (1995) found that leaf total chlorophyll and carotenoids concentration decreased with increasing Cd levels. Legrady and Lang (1998) on maize and Shenker *et al.* (2001) on wheat and barely revealed that chlorophyll and carotenoid contents decreased by Cd toxicity compared with untreated plants. The inhibition of photosynthesis by Cd in wheat seedlings was at the level of the water splitting system at the oxidizing site of PS II. The site of inhibition could also be closer to the PS II reaction center, with an additional site of inhibition at the plastquinone level (Atal *et al.*, 1991).

Data in Table (4) demonstrate that the application of Halex 2 or garlic extract caused significant increment in chl. a, chl. b, total chlorophyll (a+b) and carotenoids concentration in wheat leaves. In this respect, the inoculation with Halex 2 showed the greatest mean values. In this connection, Barakat and Gabr (1998) reported that Halex 2 significantly increased tomato leaf chlorophyll. Moreover, El-Desouky *et al.* (1998) found that the application of garlic extract significantly increased chlorophyll a and b as well as carotenoids in squash leaves. The positive effect of garlic extract on photosynthetic pigments could be attributed to the increment of cytokinins, which enhance and accelerate the conversion of proplastids into chloroplasts (Kulaeva, 1979).

As for the interaction between cadmium treatments and biofertilizer or garlic extract application, it can be noticed that, these substances alleviated the harmful effects of cadmium pollution and significantly improved photosynthetic pigments, especially under higher cadmium concentration (300 mg/l) (Table, 4). Similar results were obtained by Hamdia and El-Komy (1998) who reported that the inoculation of maize plants with *Azospirillum* significantly increased chlorophyll and carotenoid concentration under stress condition.

Table (4): Photosynthetic pigments and total soluble sugars concentration (mg/g dwt.) in wheat leaves affected by cadmium treatments, the application of biofertilizer (Halex 2) or garlic extract and their interaction in 2003/2004 and 2004/2005 seasons after 80 days from sowing.

Treatments		Chl. a		Chl. b		Chl. a + b		Carotenoids		Total soluble sugars	
Cd levels mg/l	Bio or Gr	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		4.31 a	4.79 a	1.92 a	2.14 a	6.23 a	6.93 a	2.67 a	2.92 a	28.48 a	31.18 a
75		3.62 b	4.01 b	1.58 ab	1.98 a	5.20 b	5.99 b	2.12 ab	2.27 b	24.38 ab	27.74 ab
150		3.07 c	3.26 c	1.14 bc	1.31 b	4.21 c	4.57 c	1.38 bc	1.50 c	20.44 bc	23.97 bc
300		1.79 d	2.17 d	0.74 c	0.96 b	2.54 d	3.13 d	0.99 c	1.10 c	17.55 c	20.23 c
	Control	2.03 c	2.39 c	0.94 b	1.28 b	2.97 c	3.67 c	1.29 b	1.44 b	17.46 b	20.09 c
	Bio	4.54 a	4.65 a	1.65 a	1.88 a	6.19 a	6.53 a	2.21 a	2.39 a	28.42 a	31.84 a
	Gr	3.03 b	3.64 b	1.45 a	1.63 ab	4.48 b	5.27 b	1.87 ab	2.02 a	22.26 b	25.42 b
0	Control	2.97 f	3.16 f	1.26abcde	1.41 cdef	4.23 e	4.57 d	2.12 abcd	2.23 bcde	21.00 bcd	23.87 bcd
	Bio	5.91 a	6.05 a	2.35 a	2.63 a	8.26 a	8.68 a	3.01 a	3.37 a	36.75 a	39.13 a
	Gr	4.05 d	5.16 b	2.15 ab	2.38 ab	6.20 c	7.54 b	2.88 ab	3.15 ab	27.69 abc	30.54 abc
75	Control	2.09 h	2.78 h	1.03 bcde	1.81abcde	3.12 f	4.59 d	1.34 bcd	1.58 defg	18.38 cd	21.19 cd
	Bio	5.07 b	4.98 c	1.90 abc	2.15 abc	6.97 b	7.13 b	2.78 abc	2.87 abc	29.94 ab	33.73 ab
	Gr	3.71 e	4.26 e	1.81 abcd	1.99 abcd	5.52 d	6.25 c	2.23 abcd	2.37 bcd	24.81 bc	28.31 abc
150	Control	1.95 h	2.37 i	0.92 cde	1.14 def	2.87 f	3.51 e	1.03 d	1.15 fg	16.75 cd	19.37 cd
	Bio	4.40 c	4.39 d	1.36abcde	1.62bcdef	5.76 cd	6.01 c	1.82 abcd	1.94 cdef	25.19 bc	29.73 abc
	Gr	2.87 fg	3.02 g	1.13 bcde	1.18 def	4.00 e	4.20 d	1.29 bcd	1.41 efg	19.38 bcd	22.80 bcd
300	Control	1.12 j	1.23 k	0.53 e	0.77 f	1.65 h	2.00 f	0.68 d	0.78 g	13.69 d	15.93 d
	Bio	2.78 g	3.16 f	0.98 cde	1.12 def	3.76 e	4.28 d	1.23 cd	1.37 efg	21.81 bcd	24.75 bcd
	Gr	1.48 i	2.12 j	0.72 de	0.98 ef	2.2 g	3.10 e	1.06 d	1.15 fg	17.15 cd	20.01 cd

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

b- Total Soluble Sugars, Total Carbohydrates and Total Free Amino Acids

Analysis of variance show that total soluble sugars, total carbohydrates and total free amino acids concentrations in leaves of cadmium polluted plants were significantly decreased, particularly at 300 mg/l cadmium (Tables, 4 & 5). At this level, the reduction in total soluble sugars was 38.38% and 35.12% as well as in total carbohydrates was 36.25% and 34.62% during the first and second seasons, respectively. The decrease in total free amino acids reached to 48.59% and 44.84% in the first and second seasons, respectively. Similar results were observed by Kavita and Dubey (1998) who mentioned that Cd at rates of (50-500 uM) decreased amino acids levels in rice seedlings.

This inhibitory effect of cadmium pollution on total carbohydrates in wheat leaves may be attributed to its negative effects on photosynthetic pigments, which was previously discussed.

Presented data indicate that inoculation of wheat plants with Halex 2 or application of garlic extract significantly increased these respects. The highest mean values of total soluble sugars and total carbohydrates were recorded in plants inoculated with Halex 2, meanwhile, the highest total free amino acids mean values were observed in plants treated with garlic extract. In this concern, El-Ghinbihi and Ali (2001) reported that Halex 2 significantly increased total soluble sugars in potato leaves.

Results recorded in Tables (4 & 5) mention that under cadmium treatments, the inoculation with Halex 2 or using garlic extract not only eliminated the inhibitory effect of cadmium pollution but also increased total soluble sugars, total carbohydrates and total free amino acids compared with the control plants. This promoting effect of biofertilizer or garlic extract was more pronounced at higher cadmium concentration. In this concern, Hamdia and El-Komy (1998) suggested that inoculation with *Azospirillum* increased soluble saccharide concentration in maize plants under stress condition.

c- Peroxidase and phenoloxidase activities

As seen in Table (5) peroxidase and phenoloxidase activities were significantly depressed in leaves of cadmium polluted wheat plants. The maximum reduction was observed under higher Cd concentration (300 mg/l) and reached about 34.29% and 30.77% for peroxidase and phenoloxidase activities, during the first season, respectively, compared with unpolluted plants. In this regard, Kavita and Dubey (1998) found that Cd treatments decreased protease and peptidase activities in germinating rice seeds. Moreover, Shah and Dubey (1998) suggested that increasing Cd concentration led to significant decline in the activities of phosphatases in rice seedlings.

Table (5): Total carbohydrates, total free amino acids, enzymatic activities and proline concentration in wheat leaves affected by cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction in 2003/2004 and 2004/2005 seasons after 80 days from sowing.

Treatments		Total carbohydrates (mg/g dwt.)		Total free amino acids (mg/g dwt.)		Peroxidase activity (O. D./g fresh wt.)		Phenoloxidase activity (O. D./g fresh wt.)		Proline (ug/g dwt.)	
Cd levels mg/l	Bio or Gr	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second season
0		239.79 a	247.53 a	90.18 a	93.92 a	0.70 a	0.76 a	0.39 a	0.42 a	408.49 d	419.22 d
75		218.86 b	224.88 b	74.39 b	78.29 b	0.61 ab	0.66 ab	0.36 a	0.39 a	476.51 c	493.55 c
150		176.77 c	186.17 c	62.90 c	68.33 c	0.53 bc	0.59 bc	0.32 ab	0.35 ab	544.68 b	559.07 b
300		152.87 d	161.83 d	46.36 d	51.81 d	0.46 c	0.50 c	0.27 b	0.29 b	593.54 a	607.04 a
	Control	178.86 c	188.94 c	54.18 c	59.40 c	0.39 c	0.44 c	0.21 c	0.23 c	554.60 a	567.59 a
	Bio	218.83 a	226.65 a	69.87 b	74.12 b	0.59 b	0.65 b	0.33 b	0.36 b	503.62 b	519.64 b
	Gr	193.53 b	199.73 b	81.33 a	85.75 a	0.74 a	0.80 a	0.47 a	0.50 a	459.19 c	471.93 c
0	Control	221.88 c	228.12 d	68.58 f	70.21 f	0.56 bcd	0.61 cde	0.24 efg	0.26 de	438.37 f	446.13 h
	Bio	261.25 a	270.17 a	91.26 b	94.87 b	0.69 abc	0.74 bc	0.39 bcd	0.43 abc	403.10 h	417.31 j
	Gr	236.25 b	244.31 c	110.70 a	116.67 a	0.84 a	0.93 a	0.55 a	0.58 a	384.00 i	394.21 k
75	Control	205.00 e	210.32 f	62.78 h	67.13 h	0.41 def	0.47 ef	0.22 fg	0.24 de	543.50 c	565.74 d
	Bio	240.94 b	249.53 b	75.47 d	79.32 d	0.62 abcd	0.69 bcd	0.35 cdef	0.38 bcd	465.42 e	481.36 g
	Gr	210.63 d	214.79 e	84.92 c	88.43 c	0.79 ab	0.83 ab	0.51 ab	0.55 a	420.60 g	433.54 i
150	Control	161.88 h	175.11 j	51.98 j	59.54 j	0.32 ef	0.39 fg	0.20 g	0.21 e	599.44 b	608.77 c
	Bio	195.63 f	203.16 g	64.40 g	68.83 g	0.56 bcd	0.62 cde	0.31 defg	0.34 bcde	540.70 c	561.33 d
	Gr	172.81 g	180.24 i	72.33 e	76.63 e	0.70 abc	0.76 abc	0.46 abc	0.49 ab	493.89 d	507.12 f
300	Control	126.69 j	142.19 l	33.36 l	40.72 l	0.25 f	0.28 g	0.18 g	0.20 e	637.10 a	649.73 a
	Bio	177.50 g	183.72 h	48.33 k	53.46 k	0.49 cde	0.53 def	0.26 defg	0.28 cde	605.25 b	618.55 b
	Gr	154.43 i	159.57 k	57.38 i	61.25 i	0.63 abcd	0.68 bcd	0.37 bcde	0.39 bcd	538.27 c	552.84 e

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

Obtained results demonstrate that the usage of Halex 2 or garlic extract caused significant enhancement in the enzymatic activities. The application of garlic extract showed higher significant increases in enzymatic activities than Halex 2, especially, under different cadmium levels. The stimulating effect of garlic extract on the studied enzymatic activities may be attributed to the fact that disulfide (sulphur rich compound) is a natural garlic substance, considered as an effective antioxidant and protector against lipid peroxidation (Grudzinski *et al.*, 2001). Thus, the application of garlic extract restored the enzymatic activities in all cadmium concentrations. The positive effect of biofertilizer was observed by El-Ghinbihi and Abd El-Fattah (2001) who found that under stress condition the application of Halex 2 increased peroxidase and phenoloxidase activities in taro plants.

d- Proline Concentration

Results presented in Table (5) show that pollution with cadmium significantly increased proline accumulation in wheat leaves compared with unpolluted plants. The greatest value was obtained at a high cadmium level (300 mg/l) and reached about 45.3% and 44.80% in the first and second seasons, respectively. Similar results were observed by Nagoor and Vyas (1998) who found that Cd levels increased the accumulation of proline in wheat seedlings. Furthermore, accumulation of proline is suggested as a biochemical marker for heavy metal stress. The stress signal should induce a loss of feedback inhibition of the key enzyme of proline biosynthesis (Delauney and Verma, 1993), which results in proline accumulation.

Data in the same Table indicate that the inoculation with Halex 2 or the use of garlic extract significantly depressed proline accumulation in wheat leaves. In this regard, garlic extract was more effective than Halex 2 and reduced proline concentration by 17.2% and 16.85% in the first and second seasons, respectively.

The interaction between cadmium levels and the application of biofertilizer or garlic extract show that under Cd pollution the use of these natural substances markedly reduced the accumulation of proline in wheat leaves. The maximum reduction in proline concentration was obvious under garlic extract treatment at 300 mg/l cadmium (Table, 5). In this regard, El-Ghinbihi and Abd El-Fattah (2001) showed that under stress condition the inoculation with Halex 2 reduced proline accumulation in taro leaves.

e- Mineral Concentration

Nitrogen (N) Concentration (%)

Data recorded in Table (6) indicate that N concentration (%) was higher in wheat leaves followed by grains, stems and roots. The use of lower cadmium level (75 mg/l) caused a significant decrease in N concentration of roots and grains, meanwhile, no significant reduction in N concentration of leaves in

Table (6): Effect of cadmium concentrations, application of biofertilizer (Halex 2) or garlic extract and their interaction on N and P concentration (%) in wheat leaves, stems, roots (after 80 days from sowing) and grains (after 120 days from sowing) during 2003/2004 and 2004/2005 seasons.

Cd levels mg/l	Bio or Gr	N concentration (%)							
		Leaves		Stems		Roots		Grains	
		First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		3.48 a	3.61 a	3.20 a	3.35 a	2.79 a	2.92 a	3.54 a	3.60 a
75		3.07 ab	3.21 ab	2.89 a	3.02 b	2.42 b	2.57 b	3.12 b	3.23 b
150		2.60 bc	2.73 bc	2.65 ab	2.79 b	2.11 c	2.26 c	2.58 c	2.65 c
300		2.18 c	2.30 c	2.09 b	2.18 c	1.89 d	2.01 d	2.02 d	2.13 d
	Cont.	2.57 b	2.69 b	2.42 b	2.55 c	2.03 c	2.15 c	2.46 c	2.55 c
	Bio	3.13 a	3.27 a	3.03 a	3.15 a	2.64 a	2.77 a	3.15 a	3.23 a
	Gr	2.80 ab	2.94 ab	2.67 ab	2.81 b	2.24 b	2.40 b	2.83 b	2.93 b
0	Cont.	3.17 abc	3.30 abc	2.91 abc	3.08 bc	2.40 cd	2.51 c	3.15 c	3.19 d
	Bio	3.85 a	3.97 a	3.55 a	3.66 a	3.15 a	3.27 a	3.90 a	3.98 a
	Gr	3.42 ab	3.56 ab	3.15 ab	3.30 ab	2.82 b	2.96 b	3.55 b	3.61 b
75	Cont.	2.82abcd	2.94 bcde	2.61 abc	2.78bcd	2.19 e	2.31 d	2.71 e	2.83 f
	Bio	3.38 ab	3.50 ab	3.17 ab	3.30 ab	2.76 b	2.90 b	3.53 b	3.62 b
	Gr	3.01abcd	3.20 abcd	2.88 abc	2.97bcd	2.32 d	2.51 c	3.11 c	3.24 c
150	Cont.	2.35bcd	2.46 cde	2.40 abc	2.52 de	1.85 g	2.01 f	2.24 f	2.33 h
	Bio	2.84abcd	2.98abcde	2.92 abc	3.06 bc	2.45 c	2.59 c	2.90 d	2.95 e
	Gr	2.62 bcd	2.75 bcde	2.62 abc	2.79bcd	2.01 f	2.16 e	2.58 e	2.67 g
300	Cont.	1.92 d	2.06 e	1.75 c	1.81 f	1.66 h	1.77 g	1.71 h	1.84 j
	Bio	2.46 bcd	2.60 bcde	2.48 abc	2.56bcd	2.20 e	2.31 d	2.26 f	2.37 h
	Gr	2.16 cd	2.23 de	2.03 bc	2.17 ef	1.80 g	1.95 f	2.07 g	2.18 i

Cd levels mg/l	Bio or Gr	P concentration (%)							
		Leaves		Stems		Roots		Grains	
		First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		0.34 a	0.36 a	0.32 a	0.33 a	0.31 a	0.32 a	0.55 a	0.56 a
75		0.31 b	0.32 b	0.27 ab	0.28 ab	0.26 b	0.28 b	0.47 b	0.48 b
150		0.28 c	0.29 c	0.24 bc	0.25 bc	0.22 c	0.24 c	0.41 bc	0.43 bc
300		0.25 d	0.26 d	0.21 c	0.22 c	0.19 d	0.21 d	0.37 c	0.39 c
	Cont.	0.21 c	0.22 c	0.20 b	0.21 b	0.18 c	0.20 c	0.34 c	0.35 c
	Bio	0.29 b	0.31 b	0.24 b	0.25 b	0.32 a	0.34 a	0.55 a	0.56 a
	Gr	0.37 a	0.39 a	0.33 a	0.34 a	0.23 b	0.25 b	0.46 b	0.48 b
0	Cont.	0.26 g	0.27 h	0.24bcd	0.25cde	0.23d	0.25 ef	0.41def	0.43 def
	Bio	0.33 d	0.37 d	0.31abc	0.32abc	0.38a	0.40 a	0.68 a	0.69 a
	Gr	0.42 a	0.44 a	0.40 a	0.41 a	0.30bc	0.32bc	0.54 bc	0.56 bc
75	Cont.	0.21 i	0.22 j	0.21 cd	0.22 de	0.20de	0.21 fg	0.35efg	0.37 efg
	Bio	0.32 e	0.33 f	0.25bcd	0.26cde	0.33ab	0.36ab	0.57 b	0.58 ab
	Gr	0.39 b	0.40 b	0.34 ab	0.36 ab	0.24 d	0.26def	0.49bcd	0.50 bcd
150	Cont.	0.19 j	0.20 k	0.19 d	0.20 de	0.15 ef	0.17gh	0.31 fg	0.32 fg
	Bio	0.28 f	0.30 g	0.22 cd	0.23cde	0.30bc	0.31bcd	0.50bcd	0.51 bcd
	Gr	0.36 c	0.37 c	0.30abc	0.32abc	0.20de	0.22 efg	0.43cde	0.44 cde
300	Cont.	0.19 j	0.20	0.16 d	0.17 e	0.13 f	0.15 h	0.29 g	0.30 g
	Bio	0.24 h	0.26 i	0.20 d	0.21 de	0.25cd	0.27cde	0.44cde	0.47bcde
	Gr	0.31 e	0.34 e	0.26bcd	0.28bcd	0.17ef	0.20 gh	0.38defg	0.40defg

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

both seasons. Increasing cadmium levels significantly decreased N concentration in all tested wheat organs. The maximum negative effect of cadmium pollution on the concentration of N was observed under high cadmium level 300 mg/l. This reduction was 37.32%, 34.8%, 32.34% and 42.97% for leaves, stems, roots and grains during the first season, respectively. These results are in accordance with those obtained by El-Ghinbihi (2000) who found that N concentration in common bean, leaves, roots and seeds, was significantly decreased by increasing Cd concentrations up to 1.0 mM.

As seen in Table (6), inoculation of wheat plants with Halex 2 or addition of garlic extract significantly increased N concentration in leaves, stems, roots and grains of wheat plants. In this concern, the usage of biofertilizer led to the greatest significant mean values in all tested aspects. These results are in accordance with those obtained by Saubidet and Barneix (1998) who mentioned that inoculation of wheat plants with *Azospirillum brasilense* increased the total N concentration in roots and shoots.

With respect to the combined effect of cadmium pollution levels and biofertilizer or garlic extract treatments, data show that under heavy metal pollution biofertilizer or garlic extract limited the inhibitory effect of cadmium pollution and improved N concentration in leaves, stems, roots and grains of wheat plants. Inoculation with Halex 2 caused significant higher N mean values than garlic extract or control plants. In this connection, Hamdia and El-Komy (1998) reported that under stress condition the inoculation with *Azospirillum* increased shoot N in maize plants.

Phosphorous (P) Concentration (%)

Results in Table (6) reveal that P concentration (%) in wheat grains was higher than that in leaves, stems and roots. Data recorded in the same Table indicate that all tested cadmium levels particularly the highest rate (300 mg/l) significantly decreased P concentration in leaves, stems, roots and grains of wheat plants. The inhibitory effect of Cd on P concentration may be due to the action of cadmium on the uptake and translocation of P within plant roots (Larcher, 1980). Moreover, Shah and Dubey (1998) demonstrated that Cd concentration at rate of 500 uM decreased phosphate concentration in rice shoots by 68-77% and in rice roots by 56-66%.

Furthermore, inoculation of wheat plants with Halex 2 or applying garlic extract positively affected P concentration in all tested wheat organs. The addition of garlic extract, increased P concentration in wheat leaves by 72.9% and 73.21% and in stems by 62.5% and 62.86%, meanwhile, the inoculation with biofertilizer increased P concentration in roots by 77.53% and 70.92% as well as in grains by 61.65% and 59.49% in the first and second seasons, respectively, compared with untreated plants. These results are in line with those obtained by El-Desouky *et al.* (1998) who reported that N, P and K^+ concentration in squash fruit significantly increased after application of garlic extract.

The interaction between cadmium treatments and the addition of biofertilizer or garlic extract indicate that under cadmium pollution the usage of these natural substances significantly reduced the harmful effect of cadmium pollutant on P concentration. The promising effect of Halex 2 or garlic extract in alleviating the deleterious effect of cadmium was more pronounced at relatively higher concentration of cadmium.

Potassium (K^+) Concentration (%)

Results in Table (7) indicate that K^+ concentration (%) was higher in wheat leaves than in stems, roots and grains. Data also reveal that treating wheat plants with different cadmium levels caused a significant reduction in K^+ concentration in all tested wheat organs. In this regard, the highest reduction in K^+ concentration was recorded at 300 mg/l cadmium, at which K^+ concentration in leaves was decreased by 27.49%, in stems by 32.29%, in roots by 41.52% and in grains by 44.38% during the first season. The second season showed the same trend. The obtained results are in accordance with those observed by Hernandez *et al.* (1996) who demonstrated that the concentration of K^+ was decreased in both roots and shoots of pea seedlings exposed to cadmium treatment. The disproportionate loss of cell K^+ during Cd uptake in wheat seedlings may be related to disruption of cell membrane by Cd treatment (Atal *et al.*, 1991).

Results presented in the same Table demonstrate that Halex 2 or garlic extract treatments enhanced K^+ concentration in all tested wheat organs. In this concern, the inoculation with Halex 2 showed the greatest significant increment in K^+ concentration. Similar results were observed by Caballero-Mellado *et al.* (1992) who revealed that inoculation of wheat plants with *Azospirillum* increased the uptake of mineral ions.

Concerning the interaction between Cd pollution and natural substance treatments, data in the same Table reveal that Halex 2 or garlic extract tended to inhibit the unfavorable effect of cadmium on K^+ concentration and significantly increased K^+ concentration in all wheat organs under study. In this concern, Hamdia and El-Komy (1998) observed that inoculation of salt stressed maize plants with *Azospirillum* significantly increased K^+ concentration.

Cadmium concentration (Cd)

As seen in Table (7) and Fig. (1), cadmium accumulation in roots was higher than that in stems, leaves and grains of polluted wheat plants. Similar results were observed by Alloway (1995) who found that Cd was present in higher concentrations in the roots than in other organs of maize plants. Moreover, Nan and Cheng (2001) reported that Cd in spring wheat was highest in roots, followed by stems and low in grains.

Table (7):Effect of cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction on K^+ concentration (%) and Cd concentration (ug/g dwt.) in wheat leaves, stems, roots (after 80 days from sowing) and grains (after 120 days from sowing) during 2003/2004 and 2004/2005 seasons.

Cd levels mg/l	Bio or Gr	K^+ concentration (%)							
		Leaves		Stems		Roots		Grains	
		First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		2.69 a	2.83 a	2.55 a	2.71 a	1.36 a	1.47 a	1.25 a	1.37 a
75		2.45 ab	2.53 ab	2.29 b	2.47 b	1.10 b	1.22 ab	1.01 b	1.13 b
150		2.26 bc	2.38 bc	2.05 c	2.19 c	0.96 bc	1.09 bc	0.84 c	0. 98 c
300		1.95 c	2.10 c	1.73 d	1.88 d	0.79 c	0.91 c	0.69 d	0. 84 d
	Cont.	2.12 b	2.25 b	1.91 c	2.06 c	0.94 b	1.04 b	0.81 c	0.92 c
	Bio	2.63 a	2.73 a	2.42 a	2.60 a	1.20 a	1.33 a	1.10 a	1.25 a
	Gr	2.26 b	2.40 ab	2.13 b	2.27 b	1.03 ab	1.16 ab	0.93 b	1.07 b
0	Cont.	2.43abcd	2.59 abc	2.27 e	2.40 f	1.19 abc	1.25abcd	1.05 d	1.13 d
	Bio	3.00 a	3.10 a	2.80 a	3.02 a	1.56 a	1.67 a	1.42 a	1.59 a
	Gr	2.64 abc	2.80 ab	2.59 b	2.72 c	1.32 ab	1.48 ab	1.27 b	1.39 b
75	Cont.	2.20 bcd	2.34 abc	2.01 f	2.19 g	1.00 bcd	1.10 bcd	0.86 g	1.00 g
	Bio	2.75 ab	2.80 ab	2.53 c	2.76 b	1.25 abc	1.40 abc	1.18 c	1.29 c
	Gr	2.38abcd	2.43 abc	2.32 d	2.45 e	1.06 bcd	1.17abcd	1.00 e	1.10 f
150	Cont.	2.10 bcd	2.17 bc	1.81 g	1.96 j	0.86 bcd	0.99 bcd	0.73 i	0.87 i
	Bio	2.54 abc	2.70 ab	2.34 d	2.49 d	1.09 bcd	1.21abcd	0. 99 f	1.11 e
	Gr	2.15 bcd	2.27 bc	1.99 f	2.11 i	0.93 bcd	1.07 bcd	0.80 h	0.97 h
300	Cont.	1.73 d	1.88 c	1.56 i	1.70 l	0.70 d	0.82 d	0.61 k	0.70 k
	Bio	2.24abcd	2.31 bc	2.00 f	2.13 h	0.88 bcd	1.01 bcd	0.80 h	1.00 g
	Gr	1.88 cd	2.10 bc	1.63 h	1.80 k	0.80 cd	0.91 cd	0.66 j	0.82 j

Cd levels mg/l	Bio or Gr	Cd concentration							
		Leaves		Stems		Roots		Grains	
		First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		8.67 d	9.67 d	18.17 d	19.5 d	19.50 d	21.0 d	12.33 b	14.5 b
75		16.50 c	17.83 c	32.83 c	34.67 c	37.33 c	39.5 c	16.5 b	18.5 b
150		36.67 b	39.00 b	73.5 b	75.5 b	79.0 b	82.5 b	18.67ab	20.5 b
300		66.00 a	66.00 a	122.0 a	125.17a	154.83 a	158.33 a	26.17 a	27.67a
	Cont.	44.75 a	47.5 a	71.5 a	73.63 a	83.88 a	85.88 a	21.0 a	22.63a
	Bio	30.25 b	30.25 b	60.63 b	62.63 b	71.63 b	75.13 b	18.0 a	19.88a
	Gr	20.88 c	22.00 c	52.75 c	54.88 c	62.5 c	65.0 c	16.25 a	18.38a
0	Cont.	11.00 i	12.5 g	20.0 j	22.0 i	22.0 j	23.5 j	14.5 ab	16.0bc
	Bio	8.50 j	9.0 h	18.0 jk	19.5 ij	19.5 jk	21.0 jk	12.0 b	14.5bc
	Gr	6.50 k	7.5 h	16.5 k	17.0 j	17.0 k	18.5 k	10.5 b	13.0 c
75	Cont.	20.5 f	22.0 e	39 g	40.5 g	45.50 g	47.0 g	19.0 ab	20.5abc
	Bio	16.0 g	17.5 f	31 h	33.0 h	36.0 h	38.5 h	16.5 ab	18.0abc
	Gr	13.0 h	14.0g	28.5 i	30.5 h	30.50 i	33.0 i	14.0 b	17.0 bc
150	Cont.	57.5 c	61.0b	87.0 d	89.0 d	98.0 d	100.0 d	21.5 ab	23.0abc
	Bio	30.5 e	32.5 d	71.5 e	73.0 e	78.0 e	84.0 e	18.0 ab	20.0abc
	Gr	22.0 f	23.5e	62.0 f	64.5 f	61.0 f	63.5 f	16.5 ab	18.5abc
300	Cont.	90.0 a	94.5 a	140.0 a	143.0 a	170.0 a	173.0 a	29.0 a	31.0 a
	Bio	66.0 b	62.0 b	122.0 b	125.0 b	150.0 b	157.0 b	25.5 ab	27.0 ab
	Gr	42.0 d	43.0 c	104.0 c	107.5 c	141.5 c	145.0 c	24.0 ab	25.0abc

Values marked with same alphabetical letter (s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

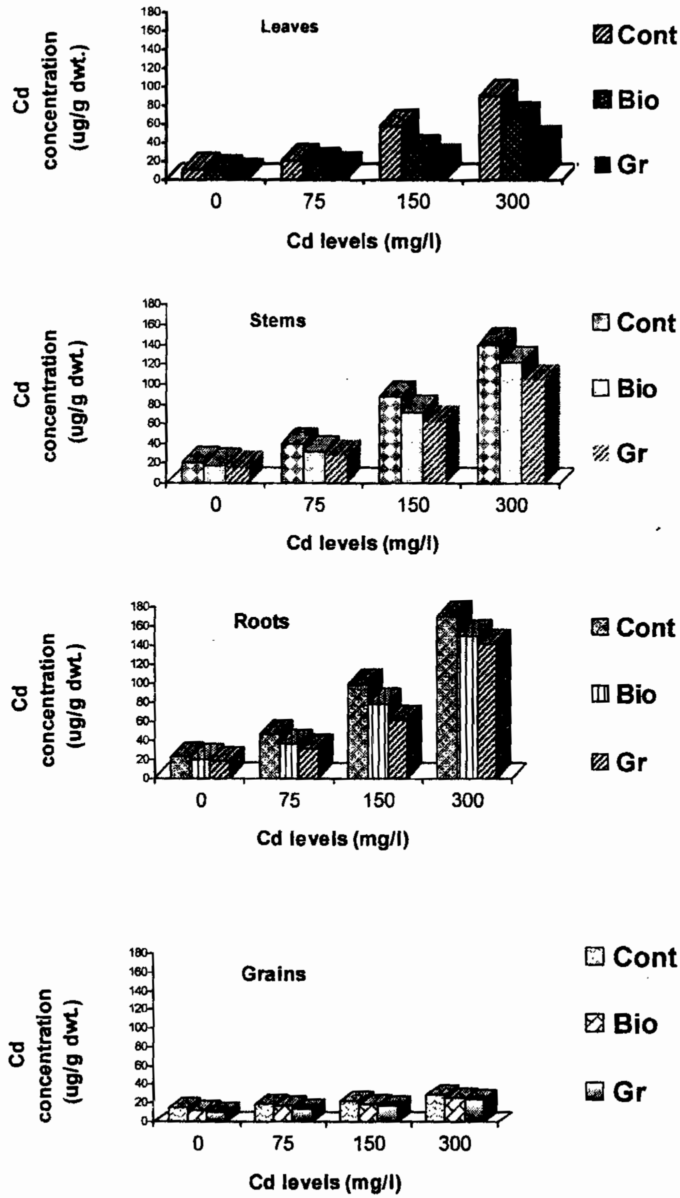

Fig. (1): Effect of cadmium levels, application of biofertilizer or garlic extract on Cd concentration in wheat leaves, stems, roots and grains during 2003/2004 season.

Obtained data show that increasing cadmium levels up to 300 mg/l in root media caused high significant increases in its concentration in roots, leaves and stems. On the other hand, the application of 75 and 150 mg/l cadmium showed no significant increases in its concentration in wheat grains compared with untreated plants. In this concern, Baker *et al.* (1990) revealed that most of Cd accumulated in the roots of the plants. Detoxification may be metal specific with Cd bound to sulphur containing proteins which form metabolically inactive complexes and accumulate in roots. These results suggest that restricted root-to-shoot Cd translocation may limit Cd accumulation in wheat grain by directly controlling Cd translocation from roots during grain filling, or by controlling the size of shoot Cd pools that can be remobilized to the grain (Harris and Taylor, 2004).

The addition of biofertilizer or garlic extract to the root media significantly decreased Cd accumulation in wheat leaves, stems and roots. No significant differences were detected between the control plants and the application of biofertilizer or garlic extract on the concentration of Cd in wheat grains.

It can be noticed that, under cadmium pollution treatments the application of biofertilizer or garlic extract significantly reduced the accumulation of Cd in wheat organs compared with untreated plants (Table, 7 and Fig., 1).

f- Total Protein Concentration (%)

Data recorded in Table (8) show that the concentration (%) of total protein was higher in wheat leaves followed by grains, stems and roots. Treating wheat plants with different Cd levels depressed total protein concentration significantly in all tested wheat organs. At higher cadmium concentration (300 mg/l), the maximum reduction in protein concentration was noticed. These results are in agreement with those obtained by Nagoor and Vyas (1998) who reported that higher cadmium concentration decreased protein concentration in wheat seedlings.

Analysis of variance demonstrate that the application of Halex 2 or garlic extract improved total protein concentration, in this concern, the inoculation with Halex 2 caused the maximum increase in protein concentration. Biofertilizer inoculation may play an important role in the protein biosynthesis either by direct nitrogen supply (through fixation of nitrogen) or indirectly by enhancing the uptake of soil nitrogen and/or by enhancing the photosynthetic apparatus (Hamdia and El-Komy, 1998).

The interaction between cadmium stress treatments and Halex 2 or garlic extract show that these natural substances markedly eliminated the negative effect of cadmium treatments and significantly increased total protein concentration. In this regard, El-Ghinbihi and Abd El-Fattah (2001) observed that under stress condition the inoculation of taro plants with Halex 2 increased protein concentration.

Table (8): Protein concentration (%) in leaves, stems, roots (after 80 days from sowing) and grains (after 120 days from sowing) of wheat plants affected by cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction during 2003/2004 and 2004/2005 seasons.

Treatments		Protein concentration (%)							
Cd levels mg/l	Bio or Gr	Leaves		Stems		Roots		Grains	
		First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		19.15 a	19.86 a	17.62 a	18.40 a	15.34 a	16.04 a	19.44 a	19.77 a
75		16.89 b	17.49 b	15.89 b	16.61 b	13.32 b	14.14 b	17.15 b	17.77 b
150		14.31 c	15.03 c	14.56 b	15.34 b	11.58 c	12.41 c	14.16 c	14.59 c
300		12.00 d	12.63 d	11.49 c	12.01 c	10.38 d	11.07 d	11.09 d	11.72 d
	Control	14.12 b	14.65 c	13.31 b	14.01 c	11.14 c	11.84 c	13.51 c	14.01 c
	Bio	17.22 a	17.96 a	16.67 a	17.32 a	14.52 a	15.23 a	17.32 a	17.77 a
	Gr	15.42 b	16.15 b	14.69 b	15.44 b	12.30 b	13.18 b	15.56 b	16.11 b
0	Control	17.45 bc	18.12 c	16.02 bc	16.93 bc	13.20 C	13.82 c	17.35 c	17.53 c
	Bio	21.18 a	21.86 a	19.53 a	20.14 a	17.33 a	18.01 a	21.45 a	21.91 a
	Gr	18.81 ab	19.59 b	17.33 ab	18.13 ab	15.50 b	16.30 b	19.54 b	19.88 b
75	Control	15.53 bcde	15.63 de	14.37 bc	15.31 cd	12.03 d	12.71 d	14.92 e	15.58 e
	Bio	18.57 ab	19.25 b	17.45 ab	18.16 ab	15.19 b	15.93 b	19.43 b	19.89 b
	Gr	16.57 bcd	17.58 c	15.86 bc	16.36 bcd	12.73 cd	13.78 c	17.12 c	17.84 c
150	Control	12.93 efg	13.55 f	13.21 cd	13.84 de	10.20 f	11.08 ef	12.34 g	12.83 g
	Bio	15.60 bcde	16.41 d	16.07 bc	16.87 bc	13.48 c	14.26 c	15.93 d	16.23 d
	Gr	14.40 cdef	15.14 e	14.40 bc	15.32 cd	11.07 e	11.90 de	14.21 f	14.71 f
300	Control	10.56 g	11.31 h	9.63 e	9.97 f	9.15 g	9.75 g	9.42 i	10.10 i
	Bio	13.54 defg	14.31 f	13.66 cd	14.10 de	12.08 d	12.72 d	12.45 g	13.06 g
	Gr	11.90 fg	12.28 g	11.18 de	11.95 ef	9.91 fg	10.74 f	11.40 h	12.01 h

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

3- Yield and its Attributes

As shown in Tables (9 & 10) yield and its components of wheat plants were significantly affected by Cd treatments. All cadmium pollution levels decreased spikes number and weight/plant, spike length, spikeletes number/spike, grains number and weight/spike, grain yield/plant, 1000 grains weight and straw yield/plant. The obtained results indicate that the pronounced negative effect of cadmium pollution was observed under higher cadmium level (300 mg/l) and caused a highly significant reduction in yield and its components.

The highest reduction in wheat yield and its attributes was observed in grain yield under 300 mg/l and reached up to 81.03% as compared with the control plants. Similar results were obtained by El-Ghinbihi (2000) who mentioned that cadmium treatments significantly decreased common bean yield.

Data recorded in Tables (9 & 10) show that the inoculation with biofertilizer or the addition of garlic extract significantly enhanced wheat yield and its attributes. Best results were observed by applying garlic extract. In this connection, Helmy (1992) and El-Desouky *et al.* (1998) reported that the application of garlic extract significantly increased squash yield and its attributes. The positive effects of garlic extract on wheat yield may be due to the fact that garlic extract is considered as a phytoncids, a powerful antiseptic and bactericide, which made the plants more healthy and vigorous and in turn increased the yield (Konokov and Kiram, 1988). This could be attributed to the significant increase of endogenous auxins and cytokinins (El-Desouky *et al.*, 1998). The enhancing influence of biofertilizer inoculation on yield and its components was observed by Zaid (1992) on barley and Tomar *et al.* (1998) on wheat plants. The obtained yield increases may mainly be due to its stimulating effects on root growth, changing root morphology, enhancing the uptake of minerals and its involvement in phytohormones production (Noel *et al.*, 1996).

Furthermore, there were no significant differences between Halex 2 and garlic extract treatments in spikes number/plant, spike length, spikeletes number/spike and 1000 grain weight, in both seasons.

The interaction between cadmium pollution levels and biofertilizer or garlic extract treatments reveal that under cadmium treatments Halex 2 or garlic extract significantly overcame the toxicity of Cd and improved yield and its attributes. Best results were obtained by adding garlic extract under cadmium rates of 150 and 300 mg/l.

4) Grain Quality

Data presented in Table (10) show that wheat grain quality, expressed as total carbohydrates concentration, was significantly depressed as a result of treating wheat plants with different cadmium levels. Cadmium at 300 mg/l caused maximum reduction in total carbohydrates concentration. This reduction reached about 25.03% and 24.85% in the first and second seasons, respectively.

Table (9): Effect of cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction on yield and its components of wheat plants in 2003/2004 and 2004/2005 seasons after 120 days from sowing.

Treatments		Spikes number/plant		Spike length (cm)		Spikes weight/plant (g)		Spikeletes number/spike		Grains number/spike	
Cd levels mg/l	Bio or Gr	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		2.89 a	4.11 a	7.05 a	8.55 a	1.38 a	2.08 a	17.22 a	17.78 a	23.33 a	30.67 a
75		2.22 ab	3.56 ab	6.68 a	7.82 ab	1.23 b	1.85 b	16.0 ab	16.89 ab	21.22 b	26.89 b
150		1.56 bc	3.0 bc	6.26 ab	7.08 ab	1.10 b	1.42 c	14.78 bc	16.00 bc	19.11 c	23.67 c
300		1.0 c	2.44 c	5.49 b	6.38 b	0.95 c	1.14 d	13.33 c	15.11 c	16.55 d	20.22 d
	Control	1.17 b	2.75 b	6.0 a	6.68 b	1.05 b	1.21 c	14.17 b	15.5 b	17.67 c	20.25 c
	Bio	2.0 ab	3.25 ab	6.71 a	7.43 ab	1.16 b	1.70 b	15.33 ab	16.5 ab	20.58 b	26.59 b
	Gr	2.58 a	3.83 a	6.41 a	8.26 a	1.29 a	1.95 a	16.50 a	17.34 a	21.92 a	29.25 a
0	Control	1.67 bc	3.33 ab	6.5 ab	7.43 a	1.26 abc	1.46 de	16.0 abc	16.67 abc	20.67 def	25.00 cd
	Bio	3.0 ab	4.0 ab	7.53 a	8.42 ab	1.38 ab	2.16 b	17.0 ab	17.67 ab	24.33 ab	32.67 a
	Gr	4.0 a	5.0 a	7.13 ab	9.80 a	1.49 a	2.63 a	18.67 a	19.0 a	25.0 a	34.33 a
75	Control	1.33 bc	3.0 ab	6.23 ab	6.8 ab	1.14 bcde	1.33 ef	15.33abcd	16.0 abc	18.33 fg	21.00 de
	Bio	2.33 abc	3.67 ab	6.95 ab	7.9 ab	1.24 abcd	1.99 c	16.0 abc	17.0 abc	22.00 bcd	28.00 bc
	Gr	3.0 ab	4.0 ab	6.85 ab	8.75 ab	1.30 abc	2.22 b	16.67 abc	17.67 ab	23.33 abc	31.67 ab
150	Control	1.0 bc	2.67 b	5.97 ab	6.7 ab	0.99 def	1.11 g	13.33 cd	15.33 bc	17.33 g	18.67 e
	Bio	1.67 bc	3.0 ab	6.5 ab	7.0 ab	1.10 cde	1.50 de	15.0 bcd	16.0 abc	19.00 efg	25.00 cd
	Gr	2.0 abc	3.33 ab	6.3 ab	7.55 ab	1.21 bcd	1.64 d	16.0 abc	16.67 abc	21.00 cde	27.33 bc
300	Control	0.67 c	2.0 b	5.28 b	5.8 b	0.81 f	0.93 h	12.0 d	14.0 c	14.33 h	16.33 e
	Bio	1.0 bc	2.33 b	5.85 ab	6.4 b	0.90 ef	1.16 fg	13.33 cd	15.33 bc	17.00 g	20.67 de
	Gr	1.33 bc	3.0 ab	5.35 b	6.95 ab	1.14 bcde	1.32 ef	14.67 bcd	16.0 abc	18.33 fg	23.67 cd

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

Table (10): Effect of cadmium levels, application of biofertilizer (Halex 2) or garlic extract and their interaction on yield and its attributes as well as grain quality of wheat plants in 2003/2004 and 2004/2005 seasons after 120 days from sowing.

Treatments		Grains weigh (g/spike)		Grain yield (g/plant)		1000 grains weigh (g)		Straw yield (g/plant)		Total carbohydrates/grains (mg/g dwt.)	
Cd levels mg/l	Bio or Gr	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season	First Season	Second Season
0		0.62 a	1.0 a	1.95 a	4.21 a	30.34 a	36.21 a	4.74 a	7.21 a	495.34 a	497.44 a
75		0.51 b	0.76 b	1.24 b	3.30 b	26.17 b	32.04 b	3.98 b	6.10 b	461.96 b	464.65 b
150		0.42 bc	0.61 c	0.72 c	1.88 c	20.25 c	28.23 bc	3.25 b	5.02 c	394.77 c	398.17 c
300		0.34 c	0.51 d	0.37 d	1.33 d	17.39 c	24.80 c	2.43 c	3.92 d	371.34 d	373.85 d
	Control	0.30 c	0.46 c	0.38 c	1.73 c	19.35 b	23.7 b	2.41 c	4.67 b	407.66 c	410.4 c
	Bio	0.45 b	0.81 b	0.97 b	2.74 b	24.58 a	32.16 a	3.30 b	5.38 b	431.98 b	434.49 b
	Gr	0.67 a	0.90 a	1.86 a	3.58 a	26.69 a	35.11 a	5.09 a	6.64 a	452.91 a	455.69 a
0	Control	0.44 cde	0.78 cd	0.73 f	2.60 g	23.77 cd	31.10 bcd	3.08 de	5.98 bcd	467.63 d	469.21 c
	Bio	0.60 bc	1.07 ab	1.80 c	4.28 b	32.05 ab	37.00 abc	4.48 bc	6.89 b	486.5 b	489.0 b
	Gr	0.83 a	1.15 a	3.32 a	5.75 a	35.20 a	40.53 a	6.65 a	8.75 a	531.88 a	534.12 a
75	Control	0.32 def	0.48 f	0.43 g	2.99 e	20.63 def	23.70 efg	2.67 de	5.44 bcde	437.37 e	439.82 d
	Bio	0.48 cd	0.88 c	1.12 e	3.23 d	28.78 bc	34.33abcd	3.47 cd	6.16 bc	466.87 d	469.42 c
	Gr	0.72 ab	0.92 bc	2.16 b	3.71 c	29.11 bc	38.10 ab	5.80 ab	6.71 bc	481.63 c	484.70 b
150	Control	0.24 ef	0.32 g	0.24 hi	0.85 j	17.67 def	22.00 fg	2.22 de	4.15 def	383.13 h	387.63 f
	Bio	0.39 def	0.68 de	0.65 f	2.04 h	20.38 def	30.30 cde	2.91 de	4.80 cdef	397.42 g	399.77 e
	Gr	0.64 abc	0.83 cd	1.28 d	2.76 f	22.70 de	32.40 bcd	4.63 bc	6.10 bcd	403.75 f	407.11 e
300	Control	0.20 f	0.24 g	0.13 i	0.48 k	15.33 f	18.00 g	1.68 f	3.10 f	342.50 j	344.94 h
	Bio	0.31 def	0.60 ef	0.31 h	1.40 i	17.10 ef	27.00 def	2.33 de	3.67 ef	377.13 i	379.78 g
	Gr	0.50 cd	0.70 de	0.67 f	2.10 h	19.73 def	29.40 de	3.28 cd	5.0bcdef	394.38 g	396.82 ef

Values marked with same alphabetical letter(s), within a comparable group of means, do not significantly differ using revised L.S.D. test at 0.05 level.

Results in the same Table indicate that the addition of Halex 2 or garlic extract significantly increased total carbohydrates in wheat grains, the greatest mean values were observed by applying garlic extract followed by Halex 2 compared with untreated plants.

Under cadmium pollution levels the application of natural substances significantly increased total carbohydrates concentration in wheat grains (Table, 10). In this concern, El-Ghinbihi and Abd El-Fattah (2001) revealed that Halex 2 significantly increased total carbohydrates in taro corms under stress condition.

From the above mentioned results, it could be concluded that wheat growth characters, chemical composition, yield and grain quality were negatively impacted by Cd pollution. Presented data indicate that cadmium treatments decreased wheat growth, chemical composition, yield and grain quality. On the other hand, these treatments significantly increased the accumulation of proline in wheat leaves and cadmium concentration in wheat roots, leaves, stems and grains compared with untreated plants. The inoculation with biofertilizer (Halex 2) or the application of garlic extract significantly enhanced all studied growth characters, chemical compounds, yield and grain quality. The interaction between Cd pollution and biofertilizer or garlic extract application show that the addition of these natural substances eliminated the toxicity and the deleterious effects of Cd pollution and significantly increased plant growth parameters, chemical composition, yield and grain quality of wheat plants.

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تخفيف التأثيرات الضارة الناتجة عن تلوث نباتات القمح بالكادميوم باستخدام السماد الحيوى (هالكس ٢) أو مستخلص الثوم

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الملخص العربى

أجريت هذه الدراسة فى تجربتى أصص بالمزرعة التجريبية لكلية الزراعة-جامعة المنوفية خلال الموسمين الزراعيين ٢٠٠٣/٢٠٠٤ و ٢٠٠٤/٢٠٠٥ وذلك لدراسة تأثير تلوث نباتات القمح بالكادميوم وكذلك تأثير استخدام السماد الحيوى (هالكس ٢) أو مستخلص الثوم على صفات النمو الخضرى والتركيب الكيماوى والمحصول وكذلك جودة الحبوب لنباتات القمح صنف جيزة ١٦٨ وأيضا دراسة تأثير التفاعل بين هذه المعاملات المختلفة على أمكانية التغلب على التأثيرات الضارة الناتجة عن تلوث نباتات القمح بالكادميوم .

وقد عرضت نباتات القمح للتلوث بالكادميوم باستخدام كبريتات الكادميوم بتركيزات (صفر, ٧٥, ١٥٠, ٣٠٠ ملليجرام/لتر). وقد أوضحت النتائج المتحصل عليها ما يلى:

- كان للمعاملة بالكادميوم تأثيرها السلبي على صفات النمو الخضرى ممثلة فى طول النبات وطول الجذر وعدد الأشطاء وعدد الأوراق ومساحتها وكذلك الوزن الغض والجاف للجذور والمجموع الخضرى خاصة عند استخدام التركيزات العالية من الكادميوم.
- أدت زيادة تركيز الكادميوم الى حدوث نقص معنوى فى تركيز كل من صبغات البناء الضوئى (كلوروفيل أ, كلوروفيل ب , كلوروفيل أ+ب , الكاروتينيدات) والسكريات الذائبة الكلية والكربوهيدرات الكلية والأحماض الأمينية الحرة فى أوراق النبات.
- أظهرت الدراسة حدوث انخفاض معنوى فى معدل النشاط الانزيمى للبيروكسيدز والفينول أوكسيديز فى أوراق نباتات القمح الملوثة بالكادميوم بينما أدت زيادة مستويات الكادميوم الى زيادة تراكم البرولين فى أوراق القمح زيادة معنوية مقارنة بالنباتات الغير معاملة.

- أدت المعاملة بالكادميوم الى حدوث نقص معنوى فى تركيز كل من النتروجين والفوسفور والبوتاسيوم والبروتين الكلى فى أوراق وسيقان وجذور وحبوب القمح المعاملة بالكادميوم.
- أدت المعاملة بالكادميوم الى حدوث زيادة معنوية فى تركيز الكادميوم داخل أنسجة النباتات المعاملة وكانت الزيادة كبيرة فى جذور النباتات عنها فى الأوراق والسيقان بينما كانت هذه الزيادة غير معنوية فى حبوب القمح.
- أشارت النتائج الى حدوث نقص معنوى فى محصول القمح المتمثل فى عدد وطول ووزن السنابل/النبات , عدد السنيبلات/السنبلة , عدد الحبوب ووزنها/السنبلة , محصول الحبوب/النبات , وزن ١٠٠٠ حبة , محصول العشب/النبات وكذلك جودة حبوب القمح المتمثلة فى تركيز الكربوهيدرات الكلية فى النباتات المعاملة بالكادميوم بمقارنتها بغير المعاملة.
- أوضحت الدراسة أن التلقيح باستخدام السماد الحيوى (هالكس ٢) أو استخدام مستخلص الثوم أدى الى حدوث زيادة معنوية فى معظم الصفات تحت الدراسة فيما عدا البرولين المتراكم فى أوراق القمح وتركيز الكادميوم فى أنسجة النباتات المعاملة بالكادميوم.
- أظهرت النتائج أن التفاعل بين التلوث بتركيزات مختلفة من الكادميوم والتلقيح بالسماد الحيوى أو استخدام مستخلص الثوم قلل من التأثيرات الضارة الناتجة عن تلوث نباتات القمح بالكادميوم كما أدى الى تحسين وزيادة صفات النمو الخضرى والتركيب الكيماوى لأوراق القمح والمحصول ومكوناته وكذلك جودة الحبوب.