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EFFECT OF BIOLOGICAL AND CHEMICAL REMEDIATION TREATMENTS OF LEAD CONTAMINATED SOIL ON SEED YIELD PRODUCTION AND NUTRIENT UPTAKE OF COMMON BEAN (*PHASEOLUS VULGARIS* L.).

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ABSTRACT

Two pot experiments were carried out on summer season of 2005 and 2006 at the Experimental Farm, El-Bostan, Faculty of agriculture, Damanhour Branch, Alexandria University. The scope of this investigation was to study the effects of soil pollution with four different levels of lead (0, 100, 200,and 300 ppm) and five different remediation treatments : control , cattle manure (20 m^3 $fed.^{-1}$), super phosphate (45 kg P_2O_5 $fed.^{-1}$), seed inoculation of *Bacillus subtilis* (10 ml of the inoculums/pot having about 10^6 -10^8 cells) and the a mixture of (cattle manure + *Bacillus subtilis* +super phosphate) as well as their interactions on dry seed yield and some chemical contents of dry seeds of the common bean (*Phaseolus vulgaris* L.) cv. "Giza 3". Lead application at the rates of 100, 200 and 300 ppm significantly, decreased weight of dry seeds $plant^{-1}$, number and yield of dry pods and dry seeds $plant^{-1}$; and P , K and protein contents of dry seeds compared to control treatment, in both seasons. Remediation treatments, significantly increased the mean values of number and yield of dry pods and dry seeds $plant^{-1}$;and P, K and protein contents of dry seeds compared to the control; and decreased Pb content in seeds. The highest mean values of number and yield of dry pods and dry seeds $plant^{-1}$, as well as the studied chemical contents could be obtained by the application of super phosphate or mixed treatments. The obtained results

indicated generally that the application of mixed or super phosphate treatments to lead polluted soil might be considered as optimal treatments for the production of high yield and good quality of dry seeds of common bean.

INTRODUCTION

Heavy metals contaminations are the most serious environmental problems limiting plant productivity and threatening human health. Lead (Pb) is amongst the heavy metals that contribute anthropogenically to pollution of the biosphere, enter the food chain in increasingly significant amounts and affect many organs of the human body, such as the kidneys and the nervous system (Verma and Dubey, 2003). Assenato et al. (1986) reported that Pb can decrease sperm counts and increase at the same time the prevalence of morphological abnormal sperm. Also, the absorption of Pb by crops, specially its accumulation in the edible parts, is of a great concern in many countries due to its possibility of entering to the food chain. These facts have resulted in lead received much attention as one of the most important chemical pollutants of the environment.

The industrial development and population expansion experimented by many Egyptian cities during the last decades have produced a significant increase of lead emissions, mainly associated to the combustion of gasoline containing Pb additives and in consequence, the environmental contamination have become increasingly serious, as was indicated by El-Sokary (1978) who reported that Pb concentration ranged between 58 and 282 µg/g in the Egyptian soils, and the highest amounts were found in the soils adjacent to highways. These amounts decreased with increasing the distance from the road. It was also reported that the surface soil layer contained more amounts of lead than the sub surface ones. Likewise, Aly (1982) stated that Pb concentration in the cultivated soil of Lower Egypt, away from pollution sources, averaged 9-21 µg/g. On the other hand in industrial areas, the Pb contents in soils were more than 100 µg/g and reached more than 700 µg/g near a group of complex foundries. Remediation of polluted areas and the reduction of health risk have received much attention by environmental scientists, who had focused their work in the evaluation of organic and inorganic adsorbent materials for Pb immobilization in soils. Among these studies Covelo *et al.* (2004) observed that the amendment with organic matter might reduced the soluble fraction of lead in polluted agricultural soils, which was explained on the basis of chemical processes of adsorption involving the functional groups such as the carboxylates which acted as legends for Pb2+ to produce stable organometallic complexes (Piccolo and Stevenson, 1982; and Boyd *et al.*, 1981).

A significant reduction of Pb bioavailability in the soils upon addition of super phosphate was observed in lead-contaminated soils (Ma *et al.*, 1997 and Hettiarachchi *et al.*, 2001). Reduced plant uptake of Pb was also observed upon super phosphate addition to lead-contaminated soils (Hettiarachchi and Pierzynski, 2002; Cao *et al.*, 2002 and Chen and Zhu, 2004). Much knowledge about the immobilization of Pb using P amendments is needed. Recently it has been shown that rhizosphere microorganisms such as bacteria, which are suggested to be the most active organic colloids in soil, possess surfaces that interact strongly with metal ions in soil solution. They could adsorb a greater amount of heavy metals than inorganic soil components such as montmorillonite, kaolinite or vermiculite (Ledin et al., 1996), since bacterial cells (approximately 1.0–1.5 μm^3) have an extremely high ratio of surface area to volume, which endows bacteria with a strong capacity at adsorbing and immobilizing toxic ions from soil solution (Beveridge and Schultze-Lam, 1995), or by producing an enzyme that has no function in bacteria but modulates ethylene levels in developing plants (Glick et al., 1998). In addition, plant-associated bacteria may produce phytohormones and provide nutrients to the plant (Patten and Glick, 1996). Implementation of theses technologies in the field for remediation of soils and vegetables contaminated by lead is limited, especially in Egypt. Therefore, the purposes of this work was to investigate the ability of the organic manure, super phosphate and bacteria for reducing the uptake of lead by common bean plants (*Phaseolus vulgaris*) grown for seed production in soil irrigated with different levels of lead solutions.

MATERIALS AND METHODS

Experiments

During the two consecutive summer seasons of 2005 and 2006 at the Experimental Farm of El-Bostan, Faculty of Agriculture Damanhour Branch, Alexandria University, Two pot experiments were conducted to determine the effect of lead, cattle manure, *Bacillus subtilis*, super phosphate and the mixed treatment (cattle manure + *Bacillus subtilis* + super phosphate) as well as their interactions on seed production of the cultivar Giza-3 of common bean plants (*Phaseolus vulgaris* L.).

The experimental soil was silt clay (organic matter 3.12 and 3.23 %, N 110 and 120 ppm, P 32 and 36 ppm, K 426 and 440 ppm, pH 7.8 and 7.85 and, Pb 0.49 and 0.47ppm in the seasons of 2005 and 2006 respectively).The physical and chemical characteristics of cattle manure were (pH 7.5 and 7.3; EC 2.9 and 2.7 mmohs; N 0.83 and 0.84 %; P 0.46 and 0.49 %; K 1.84 and 1.75 %; C/N ratio 10 and 11; Pb content 1.15 and 1.03 ppm in the seasons of 2005 and 2006 respectively). Physical and chemical characteristics of soil and cattle manure were determined according to the methods reported by Page et al. (1982). Lead was determined according to the method mentioned by Cottenie et al., (1982). and measured by atomic absorption spectrophotometer (AAS).

Design and establishment of the experiment

The experiment was carried out in plastic pots of 25 cm inner diameter filled with four kg of the soil. The Pb-treated soil was prepared by adding lead acetate $Pb(CH_3COO)_2 .3H_2O$ to the soil at Pb concentrations of 0.0,100, 200 and 300 ppm . The Pb needed for each pot was weighted in the form of lead acetate, dissolved in 500-ml water. The Pb solution was poured into the soil slowly and the soil was mixed at the same time. The soil in pots was brought to field capacity and allowed to air-dry to insure Pb-soil equilibrium.. Five seedlings were planted in each pot. Pots were irrigated with tap water whenever it was needed to keep the moisture in soil at about 70% of the total water holding capacity of the soil during the experimental period. Plants were thinned to three plants per pot after about a week. Each treatment contained 5 pots. Plant heights of common bean plants were measured at 8 days intervals.

The experimental system was a split plots in a randomized complete blocks design with three replicates. Lead at the concentrations of 0.0,100, 200 and 300 ppm occupied the main plots; whereas, Cattle manure (20 m^3 fed.$^{-1}$), super phosphate (45 kg P_2O_5 fed.$^{-1}$), seed inoculation of *Bacillus subtilis* (10 ml of the inoculums/pot having about $10^6 - 10^8$ cells) and the mixed treatment (cattle manure + *Bacillus subtilis* +super phosphate) as well as the control were assigned at random in the sub-plots. *Bacillus subtilis* was obtained from Microbiological Resources Center, Faculty of Agriculture, Ain Shams University.

Harvesting and Plant Analysis:

Plant samples were collected for the measurement of various growth parameters; number of leaves plant^{-1}, leaves fresh weight (g) and leaves area per plant(cm^2) by using the weight method as described by Fayed (1997). Plants were finally harvested after complete maturity and the number of dry pods plant^{-1}, dry pods yield plant^{-1} (g) and dry seed yield plant^{-1} (g) were recorded.

The harvested plants were washed thoroughly with tap water and then with deionized water. The plant samples and dry seeds were oven dried at 70 C° for 48 hours to constant weight. The oven-dried samples were ground in a mill with stainless steel blades and wet digestion procedure was performed according to Chapman and Pratt (1978). The Pb concentrations of the samples were determined with Atomic Absorption spectrophotometer according Cottenie *et al.*, (1982). Phosphorus percentage of dry seeds was determined calorimetrically as reported by Jackson, (1967). Potassium percentage of dry seeds was determined by flame photometer as described by Brown and Lilliand (1946). The nitrogen contents of dry seeds were determined using micro- kjeldahl method according to Ling (1963) and protein content was calculated by multiplying the total N in seeds by 6.25.

Statistical Analysis:

Appropriate analysis of variance on result of each experiment was performed using SAS software program (1996). The revised least significant difference test was used to compare the differences among treatment's means at P= 0.05 level; as illustrated by Al-Rawy and Khalf-Allah (1980).

RESULTS AND DISCUSSION

Plant height

Data of plant height are given in Tables (1 and 2) and Figs. (1 and 2). Regarding the main effects of Pb concentration, data showed clearly that a significant decrease in plant height was observed due to lead application. Average plant height was insignificantly affected at 100 ppm Pb, as compared to control, in all time periods in both seasons. The most negative effect was found with 300 ppm lead treatment which reduced the plant height by 6.7, 10.6, 12.74 and 31.0 and by 8.8, 10.64, 13, 31 and 24.8 as compared with untreated plants in the first and the second seasons at 8, 16, 24, 32 and 40 days respectively. These results are in agreement with those obtained by El-Ghinbihi, (2000) who found that the plant height of common bean was reduced as the concentration of lead increased. Also Kastori *et al.* (1998) found that lead application at 10^{-7} – 10^{-3} M reduced plant growth due to retarded cell division and differentiation, thus inhibited their elongation in sunflower plants. Meanwhile Aly (1982) reported that the high lead concentration decreased the height of pepper and Jews mellow plants.

All remediation treatments (Tables 1 and 2) increased significantly plant height compared to control at (16, 32, 40 days) in both seasons. This increase in plant height of common bean might be due to reducing the uptake of Pb by remediation treatments (Bassuk, 1986) as well as to the presence of growth promoting substances such as indole acetic acid and gibberellins produced by microorganism applications (Lazarovites, 2001)

Data presented in Tables (1 and 2) showed that the interaction between remediation treatments and lead levels significantly affected plant height on both seasons especially at 32 and 40 days, the results also indicated that application of the mixed treatment or P at (300 ppm) overcame the deleterious effect of Pb and increased plant height by 34.9 and 34.8%; 34.9 and 34.4%, at 40 days in the 1st season and the second seasons respectively.

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Table (1). Effect of soil Pb pollution and some remediation treatments along with their interactions on plant height of common bean cv. Giza 3 during 2005 season.

Remed. treatments \ Pb(ppm)	0	100	200	300	Mean
plant height (cm) after 8 days					
Control	14.77 ab	14.39 a-f	14.49 a-e	13.75 a-g	14.35 A
Cattle manure	13.81 a-g	14.987 ab	12.10 h	13.69 a-g	13.64 AB
B.subtilis	14.54 a-d	13.62 b-g	13.13 e-h	13.24 d-h	13.63 AB
Super phosphateP	14.47 b-e	14.21 a-f	13.36 c-h	12.44 gh	13.61 B
Mixed	15.07 a	14.03 a-f	14.69 a-c	13.04 f-h	14.20 AB
Mean	14.53 A	14.25 A	13.55 B	13.23 B	
plant height (cm) after 16 days					
Control	18.28 a-d	18.37 abc	14.99 gh	14.185 h	16.46 B
Cattle manure	16.48 c-g	19.45 a	15.21 gh	15.89 gh	16.76 AB
B.subtilis	16.99 b-g	17.62 a-f	16.80 b-g	16.23 d-h	16.91 AB
Super phosphate	18.78 ab	19.32 a	16.60 c-g	16.72 b-g	17.85 A
Mixed	18.09 a-e	16.69 b-g	16.80 c-g	16.157 e-h	16.94 AB
Mean	17.72 A	18.29 A	16.08 B	15.84 B	
plant height (cm) after 24 days					
Control	22.69 a	21.40 a-d	17.05 hi	16.00 i	19.285 A
Cattle manure	19.43 d-g	22.38 ab	18.47 fgh	17.38 ghi	19.49 A
B.subtilis	20.66 a-e	21.20 a-d	20.00 c-f	18.80 e-h	20.19 A
Super phosphate	21.60 abc	20.96 a-e	19.60 c-g	19.40 c-g	20.43 A
Mixed	20.46 b-f	20.44 b-f	20.05 c-f	19.28 d-g	20.057 A
Mean	20.97 A	21.26 A	19.04 B	17.00 C	

Continue Table (1) : Effect of soil Pb pollution and some remediation treatments along with their interactions on plant height of common bean cv. Giza 3 during 2005 season.

Remed. treatments \ Pb(ppm)	0	100	200	300	Mean
plant height (cm) after 32 days					
Control	26.88 abc	25.42 bcd	15.55 hi	14.14 i	20.50 B
Cattle manure	25.96 abc	27.88 a	20.11 fg	17.58 h	22.90 A
B.subtilis	27.46 ab	26.179 abc	20.76 f	17.86 gh	23.07 A
Super phosphate	25.95 abc	25.84 a-d	23.48 de	20.70 f	24.00 A
Mixed	26.49 abc	25.04 cd	22.34 ef	20.90 f	23.69 A
Mean	26.55 A	26.07 A	20.45 B	18.24 C	
plant height (cm) after 40 days					
Control	32.16 a	31.02 abc	21.18 fg	19.55 g	25.98 B
Cattle manure	30.50 abc	32.49 a	25.59 de	24.29 e	28.22 A
B.subtilis	32.80 a	31.65 ab	26.38 de	23.33 ef	28.54 A
Super phosphate	31.65 ab	31.47 ab	28.64 bcd	26.35 de	29.53 A
Mixed	32.40 a	30.51 abc	28.00 cd	26.37 de	29.32 A
Mean	31.90 A	31.4281 A	25.96 B	23.98 C	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05.

Number of branches:

The results recorded in Tables (3 and 4) indicated that the average number of stems per plant was significantly affected by lead levels in both seasons .The estimated reductions in number of branches per plant were 6.48, 9.84 and 14.36% of the control in the first season; and 8.1, 9.4 and 14.96% in the second season at 100, 200, and 300 ppm Pb, respectively. These results are in a harmony with those reported by Attia and Moftah (2002) on borage who found that number of branches decreased with increasing lead level in soil.

All remediation treatments increased significantly number of branches per plant compared to control in both season and P and the mixed treatment were more effective than bacteria and cattle manure treatments in both seasons.

Table (2): Effect of soil Pb pollution and some remediation treatments along with their interactions on plant height of common bean cultivar measured at different time periods during 2006 season.

Pb(ppm) / Remed. treatments	0	100	200	300	Mean
plant height (cm) after 8 days					
Control	14.32 ab*	14.11 ab	14.15 ab	13.34 a-e	13.98 A
Cattle manure	13.53 a-d	14.24 ab	11.85 f	13.42 a-d	13.26 B
B.subtilis	13.96 abc	13.49 a-d	12.48 def	12.71 c-f	13.16 B
Super phosphate	13.96 abc	13.78 a-d	13.09 b-f	12.03 ef	13.21 B
Mixed	14.57 a	13.54 a-d	14.20 ab	12.64 c-f	13.74 AB
Mean	14.07 A	13.83 A	13.15 B	12.83 B	
plant height (cm) after 16 days					
Control	17.73 abc	18.00 ab	14.63 ef	13.76 f	16.03 B
Cattle manure	16.15 b-e	18.48 a	14.91 ef	15.58 def	16.28 AB
B.subtilis	16.31 b-e	17.45 a-d	15.96 cde	15.58 def	16.32 AB
Super phosphate	18.12 a	18.74 a	16.27 b-e	16.17 b-e	17.32 A
Mixed	17.49 a-d	16.11 b-e	16.25 b-e	15.67 def	16.38 AB
Mean	17.16 A	17.75 A	15.60 B	15.35 B	
plant height (cm) after 24 days					
Control	22.01 a	20.91 abc	16.64 gh	15.58 h	18.79 A
Cattle manure	19.04 c-f	21.26 ab	18.10 efg	17.33 fgh	18.93 A
B.subtilis	19.83 bcd	20.99 abc	19.03 c-f	18.13 efg	19.49 A
Super phosphate	20.85 abc	20.34 a-d	19.21 b-f	18.92 c-f	19.83 A
Mixed	19.79 b-e	19.72 b-e	19.39 b-f	18.70 d-g	19.4 A
Mean	20.30A	20.64A	18.47B	17.73C	
plant height (cm) after 32 days					
Control	26.07 ab	24.91 abc	15.18 gh	13.71 h	19.97 B
Cattle manure	25.44 ab	26.49 a	19.71 e	17.22 fg	22.21 A
B.subtilis	26.36 ab	25.92 ab	19.73 e	17.14 g	22.29 A
Super phosphate	25.04 abc	25.06 abc	23.02 cd	20.04 e	23.29 A
Mixed	25.62 ab	24.16 bc	21.61 de	20.27 e	22.91 A
Mean	25.71A	25.31A	19.85B	17.98C	

Continue : Table (2): Effect of soil Pb pollution and some remediation treatments along with their interactions on plant height of common bean cultivar measured at different time periods during 2006 season.

Pb(ppm) / Remed. treatments	0	100	200	300	Mean
plant height (cm) after 40 days					
Control	30.57 a	29.79 ab	20.26 jk	18.58 k	24.80 B
Cattle manure	29.30 abc	30.25 ab	24.58 efg	23.33 fg	26.86 A
B.subtilis	30.86 a	30.70 a	24.56 efg	21.95 hi	27.02 A
Super phosphate	29.93 ab	29.91 ab	27.50 bcd	24.98 def	28.08 A
Mixed	30.70 a	28.86 abc	26.53 cd	25.07 def	27.79 A
Mean	30.27 A	29.90 A	24.67 B	22.78 C	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05.

Significant effects for the interactions between remediation treatments and Pb levels on average number of branches per plant were noticed in both seasons (Tables 3 and 4). At the highest lead application level (300 ppm), the mixed and P treatments exhibited higher numbers of branches per plant in both seasons.

Leaves fresh weight and leaf area

Data presented in Tables (3 and 4) indicated that increasing lead levels caused significant decreases on leaves fresh weigh and leaf area in both seasons. Leaves fresh weight decreased by 6.36, 25.44 and 39.6%, in the first season and by 6.13, 25.38 and 39.69 %, in the second season as compared with untreated plants at 100 , 200 ppm , and 300 ppm , respectively .Meanwhile leaf area decreased by 11.28 , 26.41 and 48.1% in the first season and by 11.06 , 26.32 and 48.1 % in the second season relative to the untreated plants, at 100, 200ppm, and 300ppm respectively .The obtained results confirmed those reported by El-Ghinbihi (2000) who found that leaves fresh and dry weights and leaf area of common bean plants reflected clear reductions by lead treatments .

All remediation treatments increased significantly leaves fresh weight and leaf area compared to the control treatment (Tables 3 and

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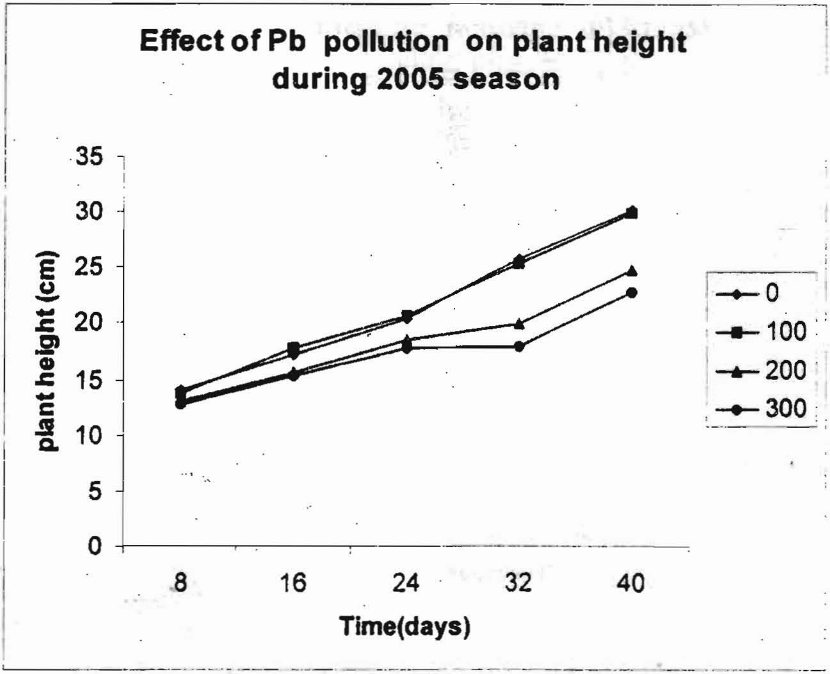

Fig. (1).The effect of Pb application levels on plant height of common bean plants v. Giza 3 measured at weekly intervals during 2005 season.

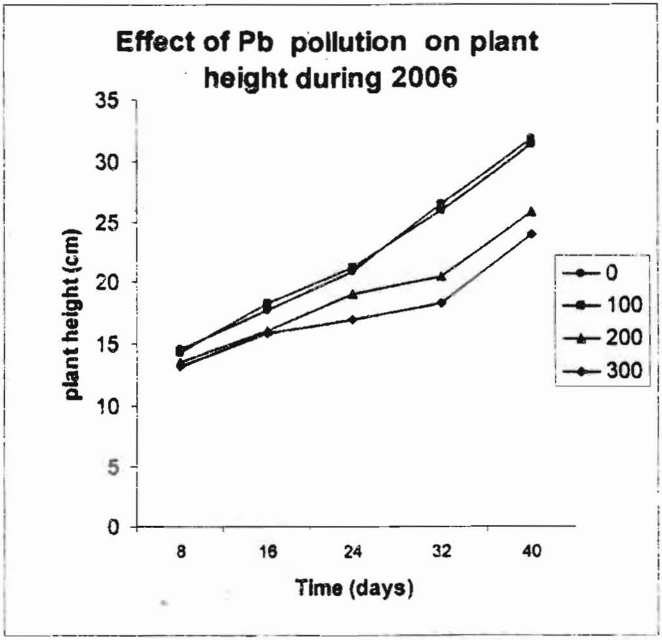

Fig. (2).The effect of Pb application levels on plant height of common bean plants cv. Giza 3 measured at weekly intervals during 2006 season.

Table (3). Effect of soil Pb pollution and some remediation treatments along with their interactions on some vegetative growth characters of common bean cv. Giza3 during 2005 season.

Pb(ppm) / Remed. treaatments	0	100	200	300	Mean
Number of branches per plant					
Control	5.20 d	4.55 i	4.44 j	4.22 l	4.60 C
Cattle manure	5.20 d	5.11 e	4.88 h	4.33 k	4.88 B
B.subtilis	5.33 c	4.99 f	4.99 f	4.55 i	4.97 B
Super phosphate	5.44 b	5.11 e	4.88 h	4.99 f	5.11 A
Mixed	5.66 a	5.33 c	4.99 f	4.89 g	5.21 A
Mean	5.37 A	5.019 B	4.84 B	4.60 C	
Leaf fresh weight g/plant					
Control	16.21 b	15.11 bc	9.91 hi	7.15 j	12.09 C
Cattle manure	18.56 a	15.49 bc	11.61 efg	9.03 i	13.67 B
B.subtilis	15.26 bc	15.43 bc	13.04 de	10.34 ghi	13.52 B
Super phosphate	16.62 b	15.43 bc	12.76 de	11.10 fgh	13.67 AB
Mixed	15.90 b	15.87 b	14.20 cd	12.22 ef	14.55 A
Mean	16.51 A	15.46 B	12.31 C	9.97 D	
Leaf area cm^2 per plant					
Control	1003.46 a	881.32 cd	586.80 g	265.55 i	684.28 C
Cattle manure	1004.89 a	882.8 cd	696.80 f	438.13 h	755.66 B
B.subtilis	981.57 ab	881.32 cd	817.72 de	595.00 g	818.9 A
Super phosphate	1034.20 a	882.13 cd	779.74 e	646.87 fg	835.74 A
Mixed	986.88 ab	917.47 bc	805.63 e	656.13 fg	841.53 A
Mean	1002.00 A	889.01 B	737.34 C	520.34 D	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05.

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Table (4). Effect of soil Pb pollution and some remediation treatments along with their interactions on some vegetative growth characters of common bean cv. Giza3 during 2006 season.

Pb(ppm) / Remed. treatments	0	100	200	300	Mean
Number of branches per plant					
Control	5.11 abc	4.33 def	4.33 def	4.11 f	4.47 C
Cattle manure	5.11 abc	4.77 bcd	4.88 bc	4.22 ef	4.74 B
B.subtilis	5.11 abc	4.88 bc	4.66 cde	4.22 ef	4.72 B
Super phosphate	5.22 ab	4.77 bcd	4.88 bc	4.77 bcd	4.91 A
Mixed	5.44 a	5.11 abc	4.77 bcd	4.78 bcd	5.02 A
Mean	5.20 A	4.77 B	4.71 Bc	4.42 C	
Leaf fresh weight g/plant					
Control	15.72 b	14.81 bc	9.68 hi	6.93 j	11.78 C
Cattle manure	18.19 a	14.71 bc	11.37 efg	8.85 i	13.28 B
B.subtilis	14.65 bc	15.28 bc	12.39 de	9.92 ghi	13.06 B
Super phosphate	16.04 b	14.97 bc	12.51 de	10.74 fgh	13.56 Ab
Mixed	15.38 b	15.31 b	13.73 cd	11.82 ef	14.06 A
Mean	16.00 A	15.02 B	11.94 C	9.65 D	
Leaf area cm^2 per plant					
Control	960.70 a	852.46 d	565.27 h	254.23 j	658.17 C
Cattle manure	971.99 a	827.76 de	673.99 g	423.79 i	724.38 B
B.subtilis	930.05 abc	861.16 cd	766.74 ef	563.77 h	780.43 A
Super phosphate	985.03 a	844.55 d	754.21 f	617.40 gh	800.3 A
Mixed	941.90 ab	873.85 bcd	768.92 ef	627.51 gh	803.04 A
Mean	957.94 A	851.95 B	705.82 C	497.34 D	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05.

4). The percentages of the increments of leaves fresh weight were13.1, 11.83, 13.1 and 20.35% in the first season and 12.73, 10.87, 15.11 and 19.35 % in the second season as a result of using cattle manure, *Bacillus subtilis*, super phosphate and the mixed treatments , respectively. Also leaf area was increased by 10.43, 19.67, 22.13 and 22.98% in the first season and by 10.1, 18.58, 21.59 and 22% in the second season by adding cattle manure, *Bacillus subtilis*, super phosphate and the mixed treatment respectively. The stimulating effects on such growth parameters might be due to the production of bacterial growth hormones and the dissolved phosphate by *Bacillus megatherium.* This result is in agreement with those obtained by Turky *et al.* (2004) who found that inoculation with phosphorin increased the weight of fennel leaves even under a lead stress compared to the lead treatments without inoculation. The stimulation effect was also explained on the ability of the bacteria to produce anti-bacterial and anti-fungal compounds that reduced hazard diseases (Pandy and Kumar, 1989). On the other hand, the favorable effects of P on growth might be due to its main effect as a growth limiting factor or due to its role in enhancing the absorption of other nutrients, beside its inhibitory effect on lead by precipitation of lead ions (Marschner, 1995).

The interaction between Pb levels and all remediation treatments on leaf fresh weight and leaf area were found significant in both experimental seasons (Tables 3 and 4). At 300 ppm Pb leaf fresh weight increased with 70.9, 55.24 and 44.6 % in the first season and with 70.6, 54.9 and 43.1% in the second season due to the application of mixed, P and bacteria. A similar effect was reflected on leaf area and the increments were 147.1, 143.6 and 127.5%, in the first season and 146.8, 142.9 and 121.76%, in the second season due to the application of mixed, P and bacteria treatments.

Yield and its component:

The results obtained in Tables (5 and 6) showed that lead treatments reflected significant depressions on dry pods number and yield plant^{-1}, as well as yield of dry seeds plant^{-1}. Comparisons among the mean values of each character indicated that raising the applied lead rate decreased significantly number and yield of dry pods and yield of dry seed plant^{-1}. At the highest lead level (300 ppm Pb) the reductions were 48.79, 58.35 and 55.81% in the first season and 47.9,

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Table (5). Effect of soil Pb pollution and some remediation treatments along with their interactions on yield and its component of common bean cv. Giza3 during 2005 season.

Pb(ppm) / Remed. treatments	0	100	200	300	Mean
Number of dry pods per plant					
Control	8.66 abc*	9.11 ab	4.22 g	3.00 h	6.25 D
Cattle manure	9.33 ab	8.55 a-d	7.33 e	4.66 g	7.52 C
B.subtilis	8.44 bcd	9.11 ab	7.55 de	5.89 f	7.69 B
Super phosphate	9.55 a	8.89 abc	7.89 cde	4.89 fg	7.80 AB
Mixed	9.33 ab	9.26 ab	8.44 bcd	4.78 g	7.96 A
Mean	9.06 A	9.01 A	7.09 B	4.642C	
Yield of dry pods per plant (g)					
Control	12.11 bc	12.50 ab	7.60 e	3.34 g	8.89 D
Cattle manure	12.45 b	11.25 c	8.19 de	5.48 f	9.34 C
B.subtilis	11.94 bc	11.78 bc	8.12 de	6.41 f	9.57 B
Super phosphate	13.63 a	11.10 c	8.48 de	5.44 f	9.68 Ab
Mixed	12.67 ab	12.20 bc	8.76 d	5.53 f	9.78 A
Mean	12.58 A	11.77 B	8.23 C	5.24 D	
Yield of dry seeds per plant (g)					
Control	8.68 bc	8.25 cd	4.76 hi	2.70 k	6.097 C
Cattle manure	9.23 b	8.96 b	5.20 gh	4.19 ij	6.88 B
B.subtilis	8.62 bc	8.88 bc	7.00 f	4.04 j	7.14 B
Super phosphate	9.98 a	8.72 bc	7.29 ef	4.26 ij	7.56 A
Mixed	8.65 bc	9.29 b	7.54 ef	4.74 hi	7.55 A
Mean	9.03 A	8.817 A	6.3587B	3.99 C	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05.

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Table (6). Effect of soil Pb pollution and some remediation treatments along with their interactions on yield and its component of common bean cv. Giza3 during 2006 season.

Pb(ppm) / Remed. treatments	0	100	200	300	Mean
Number of dry pods per plant					
Control	8.89 abc*	9.11 ab	4.22 g	3.11 h	6.33 C
Cattle manure	9.33 cb	8.66 b-e	7.66 e	4.89 g	7.63 B
B.subtilis	8.78 bcd	9.11 ab	7.78 de	6.22 f	7.97 A
Super phosphate	9.88 a	9.11 ab	7.89 cde	5.11 g	8 A
Mixed	9.55 ab	9.00 ab	8.55 b-e	4.89 g	8 A
Mean	9.29 A	9 A	7.22 B	4.84 C	
Yield of dry pods per plant (g)					
Control	12.49 bcd	12.75 bc	7.79 fg	3.44 j	9.12 D
Cattle manure	12.70 bc	11.84 cd	8.35 ef	5.59 h	9.62 C
B.subtilis	12.44 bcd	12.33 bcd	8.54 ef	5.60 h	9.73 BC
Super phosphate	14.12 a	11.45 d	8.66 ef	5.72 h	9.98 B
Mixed	13.19 ab	12.21 bcd	9.06 e	6.67 gh	10.28 A
Mean	12.99 A	12.115 B	8.48 C	5.40 D	
Yield of dry seeds per plant (g)					
Control	9.00 bc	8.41 cd	4.88 gh	2.78 j	6.27 C
Cattle manure	9.42 b	9.35 b	5.31 fg	4.27 i	7.09 B
B.subtilis	8.25 d	9.38 b	7.36 e	4.54 h	7.08 A
Super phosphate	10.34 a	8.99 bc	7.44 e	4.41 hi	7.79 A
Mixed	9.67 ab	9.285 b	7.80 de	4.57 h	8.13 A
Mean	9.34 A	9.08 A	6.56 B	4.12 C	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

58.42 and 55.89% in the second season for number and yield of dry pods and dry seeds plant^{-1}, respectively.

All remediation treatments significantly increased number and yield of dry pods and dry seeds plant^{-1}in both seasons (Tables 5 and 6). Treating polluted soils with the mixed, P or Bacillus treatments led to increases on number of dry pods with about 27.4 , 24.8 and 23%; and 26.4, 26.4 and 25.9%, whereas yield of dry pods plant^{-1} increased by 10, 8.9 and 7.6% ;12.7, 9.4 and 6.7% over the control treatment in the first and second seasons respectively. Similary, yield of dry seeds plant^{-1} increased by 23.8, 23.9and17% ; and 29.7, 19.8and 12.9% over the control treatment; in both seasons respectively.

The increases of seed yield and its components by adding the mixed treatment (bacteria, phosphate and cattle manure) might be due to its role in removing the toxic effects of lead and production of phytohormones such as auxins and cytokinins, which could enhance plant growth; and to solubilization of minerals such as phosphorus and counteraction of the adverse effects of heavy metals on metabolic mechanisms (Kloepper *et al.*, 1989).

Chemical Contents of plant parts:

Elemental concentration

Lead content of dry seeds

Data presented in Table (7) indicated that the accumulation of lead in dry seeds differed among treatments. Lead contents increased with increase in the concentration of the applied metal. A significant higher concentration of lead in seeds was observed at 300 ppm compared to the Pb-200 or 100ppm treatments. At the highest level of Pb application (300 ppm), Pb accumulations in dry seeds were 3.24 and 3.28 µg/g dry weight, in the first and second seasons, respectively. Similar results were obtained by Moftah (2000) on tomato and eggplant and by El–Ghinbihi (2000) on common bean.

In contrast, all remediation treatments (cattle manure, *Bacillus subtilis*, super phosphate, and the mixed decreased significantly the concentrations of Pb in seeds compared to the control plants in both seasons (Table 7). There were significant differences among their ability to decrease Pb accumulation in seeds in both seasons. The reductions in lead contents in seeds were 49.7, 53.7, 54.9 and 55.2; and52.0, 55.5,58.9 and 61.8; compared to control treatment by using cattle manure, *Bacillus subtilis*, , super phosphate and mixed treatments in the first and

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Table (7). Effect of soil Pb pollution and some remediation treatments along with their interaction on the concentration of lead in seeds of common bean cv. Giza3 during 2005 and 2006 growing seasons.

Remed. treatments \ Pb	0	100	200	300	Mean
2005					
Concentration of lead (µg/g dry wt.) in seeds					
Control	0.1933 h*	4.07 b	4.17 b	4.53 a	3.26 A
Cattle manure	0.197 h	1.46 f	1.86 e	2.83 c	1.64 B
B.subtilis	0.16 h	1.46 f	1.43 f	2.96 c	1.51 BC
Super phosphate	0.183 h	1.37 g	1.5 f	2.77 cd	1.47 C
Mixed	0.17 h	1.33 g	1.57 f	2.66 d	1.46 C
Mean	0.18 D	1.94 C	2.11 B	3.15 A	
2006					
Concentration of lead (µg/g dry wt.) in seeds					
Control	0.19 i	3.80 b	4.37 a	4.40 a	3.19 A
Cattle manure	0 18 i	1.03 g	1.87 e	3.03 cd	1.53 B
B.subtilis	0.17 i	0.97 g	1.43 f	3.13 c	1.42 BC
Super phosphate	0.14 i	0.70 h	1.40 f	3.00 cd	1.31 CD
Mixed	0.14 i	0.60 h	1.30 f	2.83 d	1.22 D
Mean	0.16 D	1.42 C	2.07 B	3.28 A	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

second seasons, respectively. The order of effectiveness of these remediation treatmentson on decreasing Pb contents in seeds was the following mixed > super phosphate >*Bacillus subtilis* > cattle manure. Similar results were obtained by Bassuk (1986) who reported that Pb concentration of lettuce leaves decreased when soil was treated with cattle manure + phosphor. The role of humic substances for reducing the uptake of heavy metals was studied by Narancikova and Markovnikova (2003) and concluded that organic matter not only formed strong complexes but also might retained heavy metals in exchangeable forms. Regarding the effect of using P as a chemical agent for lead remediation, it was found that adding P to the contaminated soils reduced Pb in dry seeds by 54.9 and 58.9 compared to control in the first and second seasons, respectively .Similar results were reported by Bassuk (1986) who found that the addition of phosphor reduced Pb uptake by lettuce plants. Also Ruby et al., (1994) stated that the formation of Pb phosphates in soils contaminated with both Pb and P might be responsible for immobilizing Pb and thereby reducing its bioavailability. Xie et al. (2005) illustrated that the addition of single super phosphate significantly decreased the percentage of water - soluble and exchangeable soil Pb and reduced the uptake of Pb by cabbage plants compared to the control.

The interaction effects between remediation treatments addition and Pb rates on lead contents of dry seeds were found significant in both seasons. Remediation treatments significantly decreased Pb contents of dry seeds but with different magnitudes at different lead rates (Table 7 and Figs 3 and 4). At the highest lead application level (300ppm), data revealed that the mixed treatment reduced seeds lead contents of common bean by 41.29, and 35.68, in the first and the second seasons respectively; compared to control. Also P amendment application to 300 ppm lead contaminated soils decreased Pb contents by 38.85 and 31.82 in the first and the second seasons respectively compared to control (Figs 3and 4).

phosphorus content of dry seeds

Data presented in Table (8) showed that phosphorus contents in seeds generally, decreased significantly with increasing Pb applied rate to the soil. At the concentration of 300 ppm Pb, the percent decrease of phosphorus contents were 46.85% and 43.48% compared to control treatment in the first and the second seasons

Fig. (3) Effect of adding different remediation agents on seeds Pb content of common bean plants grown in Pb contaminated Soil during 2005 seasons

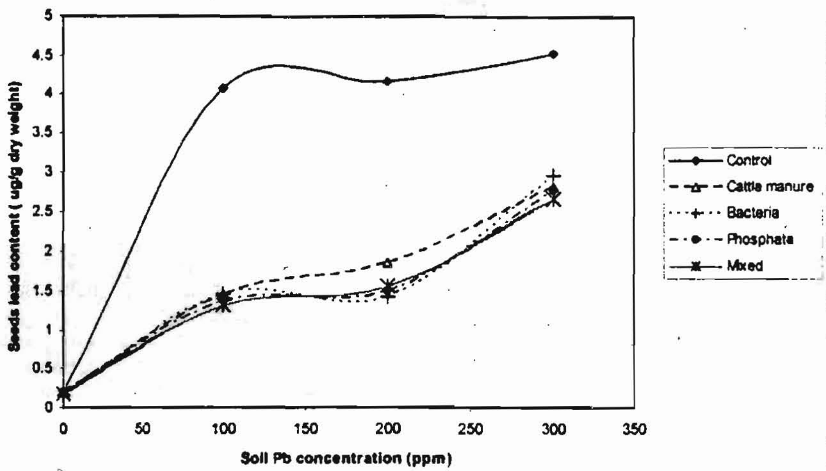

Fig. (4) Effect of adding different remediation agents on seed Pb content of commn bean plants grown in Pb contaminated soil during2006 season.

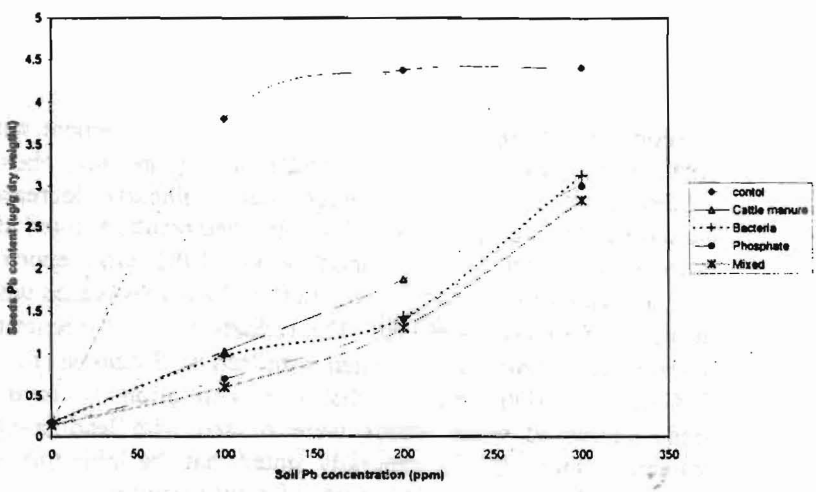

Table (8): Effect of soil Pb pollution and some remediation treatments along with their interaction on the percentage of P in seeds of common bean cv. Giza3 during 2005 and 2006 growing seasons.

Pb(ppm) / Remed. Treatments	0	100	200	300	Mean
2005					
Concentration of P(%) in seeds					
Control	0.42 c*	0.29 ef	0.213 ij	0.17 j	0.274 C
Cattle manure	0.43 c	0.32 de	0.26 fgh	0.193 j	0.3 B
B.subtilis	0.43 c	0.34 d	0.24 gh	0.203 ij	0.302 B
Super phosphate	0.51 a	0.42 c	0.33 de	0.26 fgh	0.380 A
Mixed	0.49 ab	0.45 bc	0.337 d	0.24 gh	0.378 A
Mean	0.45 A	0.364 B	0.275 C	0.213 D	
2006					
Concentration of P(%)in seeds					
Control	0.44 bc	0.3 d	0.113 g	0.127 g	0.245 D
Cattle manure	0.447 bc	0.33 d	0.243 ef	0.223 f	0.310 C
B.subtilis	0.45 bc	0.397 c	0.29 de	0.23 f	0.341 C
Superphosphate	0.51 a	0.477 ab	0.327 d	0.21 f	0.380 B
Mixed	0.507 a	0.47 ab	0.34 d	0.233 f	0.387 A
Mean	0.471 A	0.395 B	0.263 C	0.205 D	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test a P=0.05

respectively. These results seemed are in full agreement with those obtained by Attia and Moftah (2002), who found that phosphorous concentration in leaves of borage plants, linearly decreased with increasing Pb levels in the soil. The obtained results seemed also to be in accordance with those obtained by Aly (1982) who reported that P concentration of pepper and Jews mallow leaves decreased when their plants were treated with lead. The reduction in P concentration was reported in coconut leaves treated with lead by Biddappa *et al.* (1987). El-Ghinbihi (2000) noticed that P concentration of common bean seeds decreased when plants were treated with lead compared to untreated plants. It was generally stated that the inhibitory effect of heavy metal pollution on P content of plant tissues might be due to the action of pollutants on the uptake and translocation of the P element within plant roots (Larcher, 1980).

All remediation treatments significantly increased P accumulation in common bean seeds in both seasons (Table 8). The increased percentages were 9.5, 10.2, 38.7 and 38.0 %; and 26.5, 39.2, 55.1and 58.0 % compared to control for cattle manure, *Bacillus subtilis*, super phosphate, and the mixed treatment in the first and the second seasons respectively .The best results in decreasing Pb uptake were obtained from the mixed and super phosphate treatments. Meanwhile, application of super phosphate or the mixed treatment increased P (%) in seeds of common bean seeds by 38.7 and 38.0%; and 55.1 and 58.0 % compared to control in the first and the second seasons respectively. Laperche et al. (1997) reported that the addition of hydroxyapatite (HA) to Pb polluted soils led to decreased Pb concentrations in shoots of sudax (*Sorghum bicolor* L.). Therefore, formation of pyromorphite in the soil and association of P with Pb in the roots appeared to be responsible for the reduction of Pb contents in plant shoots.

The effects of Pb levels and all remediation treatments on dry seeds phosphorous content in the two seasons of 2005 and 2006 are presented in Table (8) and Figs (5and6). The results showed that remediation treatments differed significantly in their ability to increase seeds phosphorous concentrations under different Pb levels in both experimental seasons. The highest mean value of seed P content, at 200 or 300 ppm Pb, were obtained by the application of mixed or super phosphate treatments which considered, more effective than other treatments in increasing P bioavailability in the Pb contaminated soil in both seasons.

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Fig. (5) Effect of adding different remediation agents on seeds P content of common bean plants grown in Pb contaminated Soil during 2005 seasons

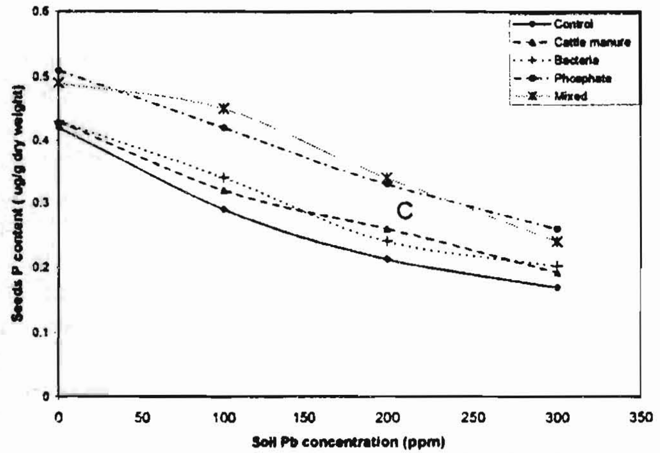
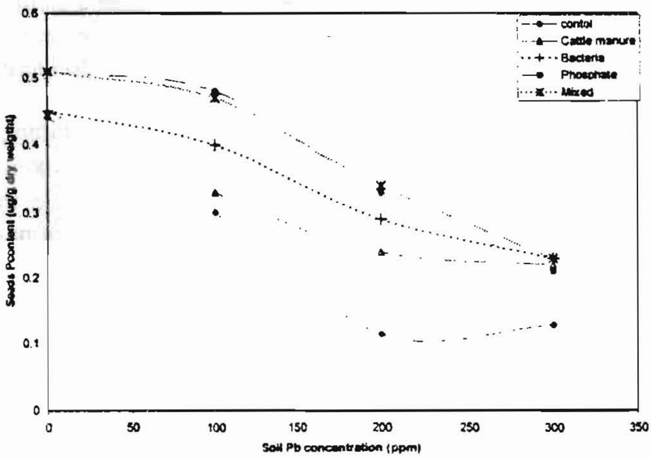


Fig. (6) Effect of adding different remediation agents on seed P content of commn bean plants grown in Pb contaminated soil during 2006 season.



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Protein contents of dry seeds

Protein contents of dry seeds in common bean plants as affected by Pb levels are shown in Table (9). Increasing Pb levels in the soil significantly decreased protein contents of dry seeds of common bean in both seasons. At 300 ppm Pb the reductions in protein content of seeds were 68.9 % and 68.8% of the control in the first and second seasons respectively. These results seemed to be in agreement with those reported by Attia and Moftah (2002) who reported that nitrogen concentration in leaves of borage plants decreased linearly with increasing Pb levels in the soil. Also El-Ghinbihi, (2000) noticed that N concentration of common bean seeds decreased when plants were treated with lead compared to untreated plants. Burzynski and Gabrowski (1984) attributed the reduction in N uptake to specific inhibitory effects of Pb due to lowering of nitrate reductase activity and disturbing nitrogen metabolism.

The main effects of remediation treatments reflected significant differences in protein contents of seeds of common bean plants in both seasons (Table 9). The mixed treatments gave the highest values of protein contents in seeds; that were estimated by 15.4% and 14.6% compared to the control in the first and second seasons, respectively.

This increasing of protein content in common bean seeds in response to some remediation treatments might be due to reduction of uptake of Pb because of these treatments. As shown from the above mentioned results, adding the mixed treatment or phosphorus as calcium superphosphate to the Pb- polluted and non polluted soils with lead significantly improved the chemical properties of common bean plants. Such a result might be due to their primitive effects on plant growth and yield as well as to their vital roles on physiological and biochemical processes in plants. In this connection, Bagal *et al.* (1989) found that protein, and mineral contents of tomato were significantly increased by increasing the rates of P application.

Significant effects for the interactions between Pb levels and remediation treatments on protein content of dry seeds were noticed in both seasons but with different magnitudes (Table 9). The comparisons among the means of protein content in seeds illustrated that the combined treatments, which included application of mixed and super phosphate and bacteria treatments with 300 ppm Pb,

Table (9). Effect of soil Pb pollution and some remediation treatments along with their interaction on protein content in green pods and seeds of common bean cv. Giza3 during 2005 and 2006 growing seasons

Pb(ppm) / Remed. teatments	0	100	200	300	Mean
2005					
Concentration of total protein (%)in seeds					
Control	23.0 abc*	19.8 de	17.54 fg	15.03 h	18.87 D
Cattle manure	22.9 abc	21.44 bc	18.62 ef	16.34 gh	19.82 C
B.subtilis	22.84 abc	20.4 cd	20.88 bc	17.16 f	20.75 B
Super phosphate	23.4 ab	23.75 ab	19.53 de	17.69 f	21.1875 B
Mixed	23.8 a	21.87 bc	20.53 cd	17.72 f	21.77 A
Mean	23.2 A	21.45 B	19.42 C	16.79 D	
2006					
Concentration of total protein (%)in seeds					
Control	21.81 ab	19.17 def	16.44 hi	14.07 j	17.89 D
Cattle manure	21.87 ab	20.59 bcd	17.44 gh	15.53 i	18.78 C
B.subtilis	23.12 a	18.9 e	20.16 cde	16.35 hi	19.78 B
Super phosphate	22.5 a	22.26 a	18.54 fg	16.58 hi	19.93 B
Mixed	23 a	20.85 bc	19.24 def	16.59 hi	20.47 A
Mean	22.43 A	20.36 B	18.36 C	15.8 D	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

appeared to be the most three effective treatments for increasing N bioavailability in the Pb contaminated soil in both seasons..

Potassium content of dry seeds

Data presented in Table (10) indicated clearly that increasing the applied Pb level up to 300 ppm significantly, decreased K content compared to control treatment in common bean seeds in both seasons. The detected reductions were 56.98% and 57.19% compared to control in the first and the second seasons respectively. Similar findings were stated by Aly (1982) who found that K concentrations of pepper and Jews mallow leaves were decreased when their plants were treated with lead .Also, El- Ghinbihi (2000) reported that K concentration of common bean roots, leaves and seeds decreased when plants were treated with lead,compared with untreated plants.

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Table (10). Effect of soil Pb pollution and some remediation treatments along with their interaction on K content in common bean cv Giza3 during 2005 growing season.

Remed. treatments \ b(ppm)	0	100	200	300	Mean
2005					
concentration of potassium % in seeds					
Control	2.65 a	1.95 f	1.62 h	0.99 j	1.80 D
Cattle manure	2.59 a	2.43 bc	2.21 e	1.37 i	2.15 C
B.subtilis	2.59 a	2.39 c	2.22 de	1.61 h	2.20 B
Super phosphate	2.62 a	2.45 bc	2.20 e	1.68 h	2.24 B
Mixed	2.60 a	2.50 b	2.30 d	1.78 g	2.29 A
Mean	2.61 A	2.34 B	2.11 C	1.49 D	
2006					
concentration of potassium % in seeds					
Control	2.67 a	1.95 f	1.42 i	1.01 j	1.76 D
Cattle manure	2.67 a	2.43 bc	2.0 df	1.41 i	2.13 C
Bacteria	2.61 a	2.39 c	2.02 df	1.64 h	2.17 BC
Super phosphate	2.65 a	2.45 bc	2 f	1.72 gh	2.20 B
Mixed	2.66 a	2.5 b	2.1 d	1.79 g	2.26 A
Mean	2.65 A	2.34 B	1.91 C	1.52 D	

*Values having a common alphabetical letter (s), do not significantly differ, using the revised L.S.D. test at P=0.05

Kabata-Pendias and Pendais (1992) explained the significant changes in internal ratios of nutrients occurred in plants under Pb were due to that Pb blocked the entry of cations (K^+, Ca, Mg, Mn, Zn, Cu, Fe^{3+}) and anions (No_3^-) in root system . Two mechanisms for decreased uptake of micro and macro nutrients under Pb toxicity were suggested by Godbold and Kettner (1991), the first mechanism, termed physical, relies on the size of metal ion radii, whereas, the second mechanism, which is a chemical one, relies on the metal – induced disorder in the cell metabolism leading to changes in membrane enzyme activities and membrane structure. The efflux of K^+ from roots, apparently due to the extreme sensitivity of K^+-ATPase and –SH groups of cell membrane proteins to Pb, is an example of the second type of mechanism.

Concerning the effects of remediation treatments, the obtained result indicated generally, that the used treatments were significantly accompanied with increasing of K contents in roots, stems, leaves, green pods and dry seeds of common bean plants compared to those of control treatment in both seasons (Table 10). The higher mean values of K in seeds were obtained from the mixed treatment in both seasons.

The results reflecting the influences of the interaction between pb levels and remediation treatments appear in Table (10) and Figs (7and 8). The comparison among the means of the various treatment combinations revealed that K contents in seeds of common bean plants responded differently and significantly to the various treatment combinations. The highest increases on K content in seeds were generally obtained from the combinations of the mixed treatment and different Pb levels, compared to the other remediation treatments.

Fig. (7) Effect of adding different remediation agents on seeds K content of common bean plants grown in Pb contaminated Soil during 2005 seasons

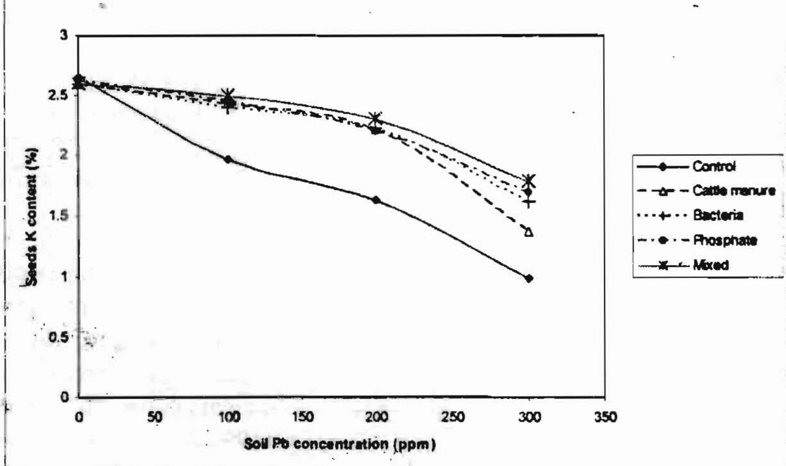

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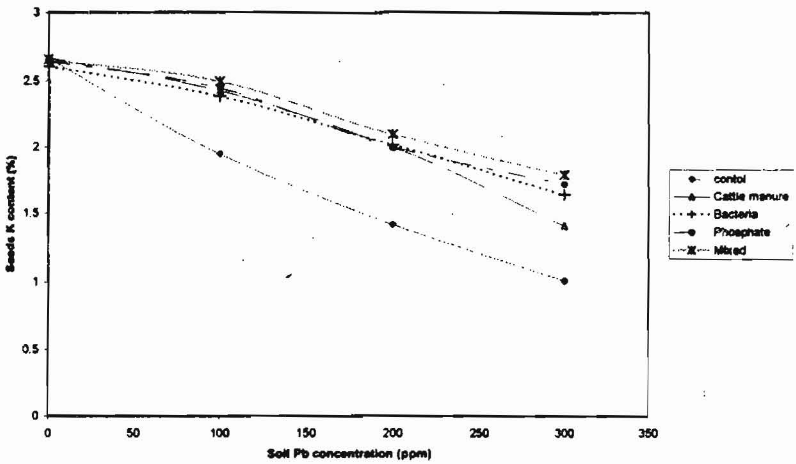
Fig. (8) Effect of adding different remediation agents on seed K content of commn bean plants grown in Pb contaminated soil during 2006 season.



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الملخص العربي

دراسة تأثير بعض معاملات البيولوجية والكيماوية لمعالجة تلوث الأراضي بالرصاص على إنتاج البذور والتركيب الكيماوي للفاصوليا

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اجريت هذه التجربة بهدف دراسة تأثير بعض معاملات معالجة تلوث الأراضى بالرصاص على بعض صفات النمو الخضري ومحصول البذور ومحتوى بذور الفاصوليا صنف جيزة 3 من عناصر الرصاص و الفوسفور والبوتاسيوم وكذلك محتواها من البروتين وقد استخدمت اربع مستويات مختلفة من الرصاص وهى 0 و100 و 200و 300 جزء في المليون وخمس معاملات معالجة وهى الكنترول ، وبكتيريا باسيلس ساتلس (10 مل تحتوى على 10^6 -10^8خلية/ اصيص) ، وروث الماشية(20م3/فدان) و سماد سوبر فوسفات الكالسيوم(45كجم فو$_2$ا$_5$/ فدان) والخليط من هذه المعالجات المختلفة والتداخلات بينهم .اجريت هذه الدراسة فى العروة الصيفية خلال موسمى 2005 ، 2006 فى مزرعة كلية الزراعة بدمنهور فى منطقة البستان بمحافظة البحيرة ، جمهورية مصر العربية ولقد صممت التجربتان بنظام القطع المنشقة باستخدام تصميم القطاعات العشوائية الكاملة بثلاث مكررات. وقد اظهرت النتائج ان تلوث التربة بالرصاص بمعدلات 100 و 200و 300 جزء في المليون قد ادى الى انخفاض معنوى فى طول النبات والمساحة الورقية.كما أدى أيضا الى انخفاض معنوى في محصول النبات من القرون و البذور للجافة وكذلك نقص محتواها من عناصر الفوسفور والبوتاسيوم وكذلك محتواها من البروتين. . وقد ارتبطت اقل القيم المسجلة لهذة الصفات بتركيز (300 جزء فى المليون) في كل من موسمي النمو. وقد أظهرت الدراسة كذلك أن إضافة معاملات المعالجة قد أدى إلى زيادة محصول النبات من القرون و البذور الجافة وكذلك ارتفاع محتوى بذور الفاصوليا من الفوسفور والبوتاسيوم و البروتين مع خفض محتواها من الرصاص. واوضحت النتائج ان افضل معاملات معالجة تلوث الاراضى بالرصاص كان باستخدام سوبر فوسفات الكالسوم اوالمعاملة بخليط من المعالجات المختلفة.