

STUDIES ON THE EFFECT OF LEAD AND SOME AGENTS FOR REMEDIATION OF LEAD IONS ON THE PERFORMANCE OF CARROT PLANT (*Daucus carota L.*)

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ABSTRACT:

During the winter seasons of 1998-1999 and 1999-2000, pot trails were conducted at the Experimental Farm, Faculty of Agriculture, Shibin El-Kom, Egypt, with aim to study the performance of carrot plant cv. "Red Core Chantenay" grown in polluted soil with lead in forms of $PbCl_2$ and $Pb(NO_3)_2$ at rates: 0, 1000, 2000 and 4000 μg Pb/g soil, without or with adding some agents for removal lead ions: Bacteria (*Bacillus subtilis*, isolate No.13) and phosphorus. Vegetative growth characters of roots and shoot were significantly inhibited with increasing the Pb concentration in soil. The inhibitory effect of Pb was more severely in the length and size of roots, root and shoot dry weights and root/shoot ratio than others characters, this effect was more pronounced in the presence of $Pb(NO_3)_2$ than in $PbCl_2$ application. Also, both Pb salt types had a deleterious effect on leaf chloroplast pigments, both chlorophyll a and b were more negative affected by Pb ions than that of carotenoids. Leaf water relations were significantly differed in responses to lead. Total water content (TWC), leaf water deficit (LWD) and transpiration were increased, whereas relative water content (RWC) was decreased as a result of Pb application. Pollution of soils with Pb significantly reduced the root, top and total yield of carrots more in the presence of Pb chloride than in that the presence of Pb nitrate. Total soluble solids (TSS) and total soluble sugars were increased, whereas carotene, vit.A, and vit.C were decreased in the roots of carrot plants treated with lead. Pb concentration in both root and top was significantly enhanced more in the presence of Pb chloride than that in the presence of Pb nitrate.

Adding *Bacillus* bacteria as a bioagent and phosphorus as a chemoagent to the Pb polluted soils not only led to overcome the deleterious effect of intolerable Pb levels (2000 and 4000 μg Pb/ g soil) on most above mentioned characters, but also stimulated the growth, increased the yield, regulated the plant water relation, protected the photosynthetic pigments and sharply reduced the Pb concentration in both root and top. Application of P was the best in this respect.

Key words: Carrot plant, lead, bacillus bacteria, phosphorus, growth, photosynthetic pigments, water relations, yield quantity and quality, lead accumulation.

INTRODUCTION:

Lead is one of the heavy metals and is considered one of the dangerous environmental pollutants. It omitted from industries, motor vehicles, stationary fuel, road dust composition and traffic roads. Lead is not only a toxic element but also can be accumulated in plant organs and agricultural products (Burzynki, 1987; Mahmoud and El-Beltagy, 1998), consequently enter human food chain (Wagner, 1993). As a result of consumption of food, lead accumulates in human body and it may cause renal failer, brain and liver damage and it can attack the nervous system and cause failing of sickness (Lucky and Kenugopal, 1977; Ramade, 1987). Lead has a deleterious effect on crop plants. It was found that the high levels of lead inhibited the growth of higher plants such as wheat (Kletecka and Niklasova, 1986; Karataglis *et al.*, 1991), vegetable crops (Ali, 1982; Xian, 1989; Moftah, 2000). Also, lead tended to have an inhibitory effect on some physiological processes, i.e. photosynthesis (Rebenchini and Harzly, 1974; Poskuta *et al.*, 1987, Becerril *et al.*, 1988), protein synthesis (Stibrova *et al.*, 1986; Taiz and Zeiger, 1998) and amino acids (McCrea, 1984; Poskuta *et al.*, 1988), carbohydrate and sugar content (Kandil, 1995), activity of some enzymes (Stibrova *et al.*, 1986), chlorophylls (Prasa *et al.*, 1989 ;

Tomasevic et al., 1991) and some water relations (Burzynki, 1987; Ewais, 1997). In addition, some investigators found that lead in soil at higher rates decreased the yield of some crops whereas the lower one had an insignificant effect on it (Xian, 1989;; Moftah, 2000). Nowadays, great efforts were made to remove or degrade and detoxify the heavy metal pollutants from water and soil using modern technology called bioremediation and phytoremediation. Many investigators used bacteria (Ibeanusi *et al.*, 1995; Cuero, 1996; Margeay et al., 1997; Mahmoud and El-Beltagy, 1998) and fungi (Gadd, 1986) as bioremediants as well as algae (Oliguin, *et al.*, 1994; Kaplan et al., 1998) and plants (Brown. 1995; Brook and Robinson, 1998) as phytoremediants. In this connection, Cuero (1996) studied the effect of the aminopolysaccharides chitosan and *Bacillus subtilis* each alone and in combination on metal accumulation in sandy loam soil contaminated with heavy metals. Mahmoud and El-Beltagy (1998) isolated and identified some lead tolerant bacteria strains from naturally lead polluted soils and tested them for lead reduction in rocket salad plant grown on polluted soils. They found that the reduction percentage of lead uptake by rocket salad plant using strains No.1 (*Streptomyces ambifaciens*), No.2 (*Streptomyces setonii*), No.13 (*Bacillus subtilis*), No. 15 (*Bacillus cereus*) and mixed were 72.6, 71.2, 96.4, 89.2 and 50.4, respectively. However, study the effect of such bioremediants on the growth, physiology and biochemistry as well as yield of plants were rare or not published. Also, application another agents as lead remediant such as nutrients or chemicals may be still under research. Moftah (2000), tested the responses of lead-polluted tomato and eggplant to the antioxidant ethylendiuarea (EDU) and found that EDU treatment seemed to be useful in the counteracting the harmful effects exerted by Pb contamination on tomato and eggplant by regulating certain enzymes.

Therefore, the aim of this investigation was to study the effect of lead pollutant in forms $PbCl_2$ and $Pb(NO_3)_2$ at different rates, with or without application bacteria (*Bacillus subtilis*, isolate No. 13) and phosphorus in form calcium superphosphate, on growth, photosynthetic pigments, water relations and yield quantity and quality of carrot as well as lead accumulation in both root and top of carrot plant.

MATERIAL AND METHODS:

Pot experiments were conducted at the Experimental Farm, Faculty Agriculture, Shibin El-Kom, Egypt. Sowing was carried out in plastic pots with 30 cm inner diameter, in October 5, 1998 and 1999 using carrot seeds cv. "Red Core Chantenay" obtained from the Horticulture Dept., Faculty of Agriculture, Minufiya University. Pots were filled with 8 kg clay loam soil taken from the Experimental Farm of Agric. Faculty of Agriculture ($EC_e=2.8$ mmhos/cm; $pH=7.9$; Soluble salts=0.16%; $Pb=68.6$ ppm). Pots were divided into two sets: first was mixed with lead chloride and the second with lead nitrate at lead concentrations 0, 1000, 2000 and 4000 $\mu g Pb/g$ soil. Each set was divided into three groups: the first without any adding agents, the second inoculated with *Bacillus subtilis*, strain No. 13 grown in NPM and the third with adding phosphorus. *Bacillus subtilis* strain No. 13 as a Pb tolerant isolate was obtained from the Agricultural Microbiology Branch, Agric. Botany Dept., Faculty of Agriculture, Shibin El-Kom, Egypt. In P treatments, phosphorus was added as calcium superphosphate (15.5% P_2O_5) at rate 4 g/pot. Pots were irrigated with tap water whenever to keep the moisture in soil at about 65% of the total water holding capacity of the soil during the experimental period.

One week before the harvest time, a random sample of 10 plants was carefully taken from each treatment and the following measurements were done:

- Vegetative growth characters: Root length (cm), root and core diameter (cm), root size (cm^3), root, shoot and whole plant dry weights (g/plant), then the root/shoot ratio was calculated.
- Photosynthetic pigments were extracted from fresh leaves using acetone 80% and estimated according to Wettstein (1957), then calculated as mg/g dry weight.
- Leaf water relations: Total water content (TWC, %), relative water content (RWC, %), leaf water deficit (LWD, %) and transpiration rate (mg/ g fwt. h) according to Kalapos (1994) and Kreeb (1990).

At the harvest time, plants in each treatments were carefully taken and cleaned then the root, top and total yield/pot were estimated then calculated as kg/m². The harvest index (%) was measured using the formula (HI= (root yield/total yield)*100). Another random sample was taken and the total soluble solids (%) using an Abe hand refractometer, vit.A (IU/100 g fwt.), vit.C. (mg/100 g fwt.) and carotene (mg/ 100 g fwt.) in fresh root were estimated using the methods of A.O.A.C. (1970). Hundred grams from the roots and tops from each treatment were dried at 70°C, 0.2 gm from each dried ground organs was acid digested for estimation the total lead concentration (µg/ g dwt.) using Atomic Absorption Spectrophotometer at Faculty of Science, Minufiya University according to Allen (1974). Another 0.2 gm from dried ground root was used to determine the soluble sugars concentration (mg/g dwt.) according to Dubois *et al.*, (1956).

A randomized complete block design with ten replicates was used. Data were statistically analyzed and the L.S.D. test at 5% level of probability was used to compare the means of the treatments (Waller and Duncan, 1969) with help the COSTAT C Statistical package (American Computer Program).

RESULTS AND DISCUSSION:

1. Vegetative growth:

Root length: Data presented in Table (1) illustrate that lead at all levels significantly inhibited the root length and it was more severely at the high Pb level. Under the intolerable level (4000 µg Pb/g soil) the reduction in it of plants grown in soil polluted with PbCl₂ and Pb(NO₃)₂ reached about 13.1 and 25.5% (1st season) and 22.4 and 34.4% (2nd season) compared with the non treated plant, respectively, indicating that Pb(NO₃)₂ had more harmful effect on root length. These results are in accordance with those obtained by Stiborova *et al.*, (1986) and Oabracheva *et al.*, (1998).

In the unpolluted soil, adding bacillus bacteria caused a slight increase in it, whereas adding P significantly increased it. In the polluted lead soils at all Pb levels, application of both bacteria and P had a high significant effect in this respect. The increase in it resulted from adding bacillus bacteria to the polluted soil with PbCl₂ and Pb(NO₃)₂ at 4000 µgPb/g soil was about 15.8 and 19.3% (1st season), 30.7 and 33.3% (2nd season), whereas with adding P to both polluted soils, the increase was about 28.6 and 17.8% (1st season), 42.3 and 35.2% (2nd season), respectively. This indicates that application P to the polluted soil with PbCl₂ and Pb(NO₃)₂ was more useful for stimulating the growth of root.

Root diameter: The same trend of root length was observed in root diameter, but the percentages of reductions in root diameter of plants grown in soil polluted with 4000 µgPb/g soil were lower (-12.8 and -19.4% for PbCl₂; -16.3 and -26.8% for Pb(NO₃)₂). Also, inoculation the lead polluted soil with bacteria or adding P had a positive effect in this respect. Again, P was more effective in this respect.

Root size: It can be seen from the same Table that the root size was sharply decreased with increasing the Pb level in soils polluted with PbCl₂ and Pb(NO₃)₂ recording the smallest size at the level of 4000 µgPb/g soil with reduction reached about -33.9 and -47.8% (1st season), -50 and -64.8% (2nd season) less than the untreated plants. Similar results were achieved by Stiborova *et al.* (1986) and Oabracheva *et al.* (1998).

Treating the lead chloride and nitrate polluted soils with bacillus led to a great increase in root size reached to about 54.6 and 76.9% (1st season), 71.1 and 96.4% (2nd season), whereas its treating with P increased it more and reached about 79.3 and 75.6% (1st season), 123.7 and 150.1% (2nd season) over the plants treated with 4000 µg Pb/g soil of two salt types.

Core diameter: A slight change in core diameter as a result of Pb treating was observed in the 1st season but a marked decrease was recorded in the 2nd one. Using bacillus

bacteria in the lead polluted soils tended to be more effective in increasing the core diameter than using phosphorus (Table, 1).

Plant height: A significant decrease in plant height was observed in the plants soils treated with 2000 (-20.9, -14.2, 1st season, and -23.01, -15.4%, 2nd season, for Pb chloride and nitrate respectively) and 4000 (-31.7, -35.3%, 1st season and -30.2, -28.2%, 2nd season) µg Pb/g soil of both salt types, whereas the low level (1000 µgPb/g soil) tended to increase it. The obtained results are in agreement with those reported by Gadallah (1995) who found that the heavy-metal toxicity appears in the reduction of plant height and dry mass accumulation.

The results obtained in Table (1) indicate that application of bacillus bacteria to the lead polluted soils by PbCl₂ and Pb(NO₃)₂ did not show a clear trend in this respect, whereas application of P overcame the deleterious effect of Pb and increased the plant height by about 22.5 and 21.8% in the 1st season, 28.5 and 21.7% in the 2nd season, respectively.

Dry weights of root, shoot and whole plant: Data presented in the same Table show that the dry weights of root and shoot as well as whole plant were significantly decreased with increasing the Pb level in soil. At the highest level of Pb (4000 µg Pb/g soil), the reduction in the dry weights of root, shoot and whole plant grown in polluted soils with PbCl₂ reached about -59.3, -43.5 and -54.2%, respectively, (1st season); -32.9, -7.8 and -23.7% (2nd season), but in the polluted soils with Pb(NO₃)₂ were about -68.9, -41.6 and -60.2% (1st season); -35.1, -5.9 and 24.5% (2nd season). These results indicate that Pb in form Pb(NO₃)₂ was more harmfully than in form PbCl₂. Similar results were obtained by Carlson et al. (1975) on maize plant, Ali (1982) on peper and jews mellow plant; Gadallah (1995) on and Begonia et al., (1998) on *Brassica juncea* plant.

Inoculating the lead chloride polluted soils with bacillus bacteria as well as adding P was not only more useful in overcame the inhibitory effect of Pb on root dry matter but also a great increase in it (97.8 and 129.3% for bacteria; 57.6 and 154.4% for P) was recorded. Shoot dry matter as well as whole plant tended to be more affected by bacillus bacteria (35.2 and 101.1% for shoot; 73.1 and 116.9% for whole plant) than that by P (16.5 and 26.6% for shoot; 41.3 and 98.1% for whole plant). Regarding the polluted soils with lead nitrate, it was found that adding both of bacillus and P showed a positive effect on root dry matter but shoot and whole dry matters tended to be more affected by P than bacillus.

Root/Shoot ratio: Data in the same Table show that a significant reduction in R/S ratio in all Pb treatments was observed. In this connection, Mishra and Choudhuri (1998) found that Pb decreased shoot/root ratio of two cultivars rice differing in their tolerance to heavy metal stress. Using both bacteria and P in the untreated and polluted soils led to a great increase in it. Bacillus was more effective in the lead nitrate polluted soil whereas P was more useful in case of the lead chloride polluted soils.

The deleterious effect of lead at the intolerable levels (2000 and 4000 µg Pb/ g soil) on growth of carrot plant may be due to lead retarded cell division and differentiation thus inhibited their elongation and that lead to a reduction in plant growth (Kastori et al., 1998). Moreover, the inhibition in root growth may be ascribed to the toxic effect of lead on the meristimatic region of root, thus retarded their growth and distribution (Stiborova et al., 1986) or/and that may be due to its inhibition effect on both cell division and elongation through the reduction of meristem size and decreasing the number of mature cells (Obroucheva et al., 1998).

The stimulating effect on growth parameters of carrot plant as a result of adding bacillus bacteria to the lead polluted soil may be attributed to action of bacteria for bioremediation of lead from contaminated soil thus inhibited its toxic effect (Ibeanusi et al., 1995), or may be due to their beneficial effect on improving nutritional status, producing growth regulators i.e. IAA, GA and cytokinins (Lazarovites, 1995; Arshad and Frankenberger, 1991) or to their ability to produce anti-bacterial and anti-fungal compounds that reduce diseases (Pandy and Kumar, 1989). As for the favourable effect of P on the growth may be due to

its effect as a growth limiting factor or due to enhancing the absorption of other nutrients (Marschner, 1995), beside its inhibitory effect on lead by precipitation of lead ions.

2. Photosynthetic pigments:

Data presented in Table (2) reveal that a sharply decrease and degradation in both chlorophyll a and b as well as total chlorophyll and carotenoids. In the lead chloride polluted soil, the percentage reduction in the above-mentioned pigments were about -90.9, -89.1, -90.2 and -44.5%, respectively, in the 1st season, and about -95.9, -90.7, -94 and -36.4 % in the 2nd one. Meanwhile in the lead NO₃ polluted soil, they were about -88.8, -53.9, -75.3 and -80.7% (1st season); -80.5, -90.7, -84.3 and -63.1% (2nd season), respectively. This indicates that Pb in any form had a severely harmful effect on all photosynthetic pigments. Similar results were reported by Burzynski (1985); Stbirova *et al.*, (1986); Sengar and Pandey (1996) and Fodor *et al.* (1998). The deleterious effect of lead on chloroplast pigments may be due to that Pb inhibits the biosynthesis of aminolevulinic acid (ALA) a precursor of chlorophyll (Thomas and Singh, 1996), and/or stimulates the activity of chlorophyllase and chlorophyll degradation (Abdel Basset *et al.*, 1995), and/or it can alter chlorophyll biosynthesis by inhibiting protochlorophyllide reductase through interfering the sulfhydryl site on the enzyme (Lagriffoul *et al.*, 1998), and/or it decreases the carotenoids that prevent chlorophyll photodestruction, or/and it inhibits Fe uptake and transport to plant leaves (Fodor *et al.*, 1998).

Treating the lead polluted soils with bacillus and P not only led to counteracting the inhibitory effect exerted by Pb but also increased their concentrations from seven to ten times for chl. a, one to five times for chl. b, one to seven times for total chlorophyll, and less or more than unit for carotenoids. P was more effective than bacillus in this respect. The role of bacteria in enhancing the photosynthetic pigments may be attributed to its indirect effect by reducing the concentration of lead ions in root medium to extent to become non toxic. The promoting effect of P on photosynthetic pigments under the normal conditions as well as the lead polluted soils may be due to its effect on reducing the concentration of lead ions as shown our results in the same work and/or due to its providing the plants with ATP and NADPH and other compounds that play a vital role in biosynthesis of chlorophylls and other pigments (Marschner, 1995).

3. Leaf water relations:

Data recorded in Table (3) indicate that the leaf total water content (TWC) tended to be decreased in the plants grown in the lead chloride polluted soils (-3.44% and -1.635% at the rate of 4000 µg Pb/g soil), whereas it tended to be increased in the lead nitrate polluted soil (+8.11 and +7.4% at the same Pb rate). In the unpolluted soils, application bacillus bacteria seemed to have not a clear effect on TWC (increased in the 1st season but decreased in the 2nd one), whereas adding P led to decrease it. In the lead-polluted soils, bacillus treatments caused a decrease in TWC ranged from 2 to 7%, whereas P treatments increased it.

Concerning the relative water content (RWC) and leaf water deficit (LWD) in relation to Pb treatments, agents treatments as well as their interactions, it was found that RWC sharply decreased in the Pb polluted soils with PbCl₂ (-14.52 and -11%) and P(NO₃)₂ (-15.5 and -12.62%) at rate 4000 µg Pb/g soil, whereas LWD was dramatically increased by 66.9 and 49.4% (chloride) and 71.4 and 56.8% (nitrate) at the same Pb rate. Treating the polluted soils with bacillus bacteria relatively improved RWC and increased it by about 7.2 and 6.6 (chloride); 11.1 and 12.3% (nitrate), whereas treating with P increased it more (15.4 and 16%, chloride; 22.6 and 19.9%, nitrate). LWD was decreased by about -16.9 and -17.7% (chloride); -25.3 and -31% (nitrate) in the polluted soils treated with bacillus, meanwhile the decrease in it was higher as a result of treating with P and

reached about -36.3 and -42.9% (chloride); -51.3 and -49.8% (nitrate). Regarding the rate of leaf transpiration (TR), data in the same Table show that TR was significantly increased under lead contamination conditions reached about 55 and 25.9% (chloride); 30.2 and 58.2% (nitrate) at rate of 4000 µg Pb/g soil. Both bacillus bacteria and P regulated the loss of water from leaves and decreased its rate. P treatment was more effective than bacillus in this respect. The obtained results agreed with those obtained by Burzysnki (1987) who found that the placement of two week old bean, wheat and cucumber plants in lead chloride solution caused a significant decrease in transpiration and water uptake.

4. Yield attributes:

Root, top and total yield: The results obtained in Table (4), show that the root and top as well as total yield of carrot were negatively affected by Pb treatments and were severely in the polluted soils with Pb chloride and nitrate at rates of 2000 and 4000 ug Pb/g soil. The highest reduction was recorded in root yield (-56.3 and -57.14, (Pb chloride); -45.8 and -58.1% (Pb nitrate)) followed by total yield (-51.8 and -49.8%, (Pb chloride), -34.8 and -45.8% (Pb-nitrate). A higher reduction in top yield was observed in the plants grown in contaminated soils with PbCl₂ (-41.5 and -33.8%) whereas a lower reduction in it (-10.1 and -19.2%) was recorded in soils with Pb(NO₃)₂ indicating that lead chloride was more harmful than nitrate. Similar results were reported by McCrea (1984) and Xian (1989) on kidney beans and Moftah (2000) on tomato and eggplant.

Adding bacillus bacteria to the lead polluted soils led to counteract the deleterious effect lead and increased the root, top and total yields by about 30.1, 35.9 and 32.3% (1st season); 72.3, 20 and 42.9%(2nd season), respectively, in the soils polluted with PbCl₂, meanwhile by about 13.5, 12.7 and 13.1% (1st season); 94.9, 3.3 and 51.9% (2nd season) in the soils polluted with Pb(NO₃)₂. Using P as a remediator for lead did not only remove the harmful effect of lead but also gave higher increases in root yield (106.4 and 65.3%), top yield (88 and 25%) and total yield (99.6 and 48.6%) in case of PbCl₂. The same trend was observed in the soil polluted soils but the percentage increases in yield were lower.

Harvest index: Data in the same Table indicate that the Harvest index (HI) was significantly decreased at all Pb levels and recorded the lowest values at the rates of 2000 and 4000 µg Pb/g soil. These reductions ranged from about 9 to 25%. Adding bacillus bacteria to the polluted soils had no significant effect on it in the 1st season but a clear increase (21.1 and 28.3%) was observed in the 2nd one. A slight increase in HI (3.4 and 4.6%) in the 1st season but a relatively increase (11.2 and 13.1%) in the 2nd one was recorded with the P treatments.

The inhibitory effect of lead on the above mentioned yield attributes of carrot may be due to its toxic effect on growth as shown our results in the same work and its inhibitory effect on the uptake and translocation of some major and micro elements within plant roots (Larcher, 1980); activity of some enzymes as well as biosynthesis of photosynthetic pigments which reflect an carrot yield. Adding bacteria or P led to a marked increase in yield components and that may be not only due to its role in removing the toxic effect of lead but also its role that play in promotion of strong root and shoot (Mohandas, 1987), the high bacterial production of phytohormones (Lazarovites, 1995), improving nutrition (Lazarovites, 1995) as well as increasing the root weight (Selim, 1999).

5. Chemical properties of roots:

Total soluble solids (TSS): Data given in Table (5) reveal that TSS was positively affected by Pb application more in the presence of lead nitrate (28.9 and 26.8%) than in lead chloride (3.8 and 5%). TSS tended to be decreased in the polluted soils and treated with

bacillus bacteria but increased in the roots of plants grown in non polluted soils. P significantly increased it in the non-polluted and polluted soils with PbCl₂, however a higher decrease (-24.1 and -21.2%) was observed by Pb(NO₃)₂.

Carotene: A significant decrease in carotene content was found in the roots of plants grown in contaminated soils with lead chloride and nitrate at rates of 2000 and 4000 µg Pb/g soil but a slight increase in it was found at rate 1000 µg Pb/ g soil (Table, 5). Treating the polluted soils with bacillus bacteria gave a great increase in root carotene content arrived to 56.5 and 110.14% in the presence of PbCl₂, and to 101.2 and 48.1% in the presence of Pb(NO₃)₂. P treatments gave higher increases in the presence of PbCl₂ (85 and 122%) but lower increases in the presence of Pb(NO₃)₂ (48.8 and 11%). Similar results were observed by Mofteh (2000) on tomato and eggplant.

Vitamin A: It was found that Vit.A was significantly decreased with increasing the Pb concentrations in the lead polluted soils, reached the lowest content at the highest rate of Pb (4000 µg Pb/g soil), (Table, 5). The deleterious effect of lead was more pronounced in the presence of PbCl₂ (-25.3 and -38%) than in the presence of Pb(NO₃)₂ (-17.6 and -21.3%). Adding bacillus bacteria to the non polluted soils caused a significant increase in it whereas in the polluted soils did not show a clear trend. Using P in both the non-polluted as well as lead chloride polluted soils resulted in increasing Vit.A, meanwhile a slight increase in the presence of lead nitrate.

Vitamin C: Data given in the same Table demonstrate that Vit.C in root was negatively affected by Pb at all concentration and was more severely at the rate of 4000 µg Pb/g soil in both salt types. The reduction in it reached about -27.4 and -30.1% in the presence of lead chloride and -49.1 and -25.6% in the presence of lead nitrate if compared with the control. Inoculation the non-polluted as well as the polluted soils by lead nitrate with bacillus bacteria led to a significant increase but not in presence of lead chloride. Adding P to the non and the polluted soils with lead (two types) overcome the deleterious effect and increased it by about +15 and +36.1 (Chloride) and +27.3 and +2.3% (Nitrate).

Soluble sugars: Data illustrated in Fig (1) showed that the total soluble, reducing and non-reducing sugars were markedly decreased under all levels of lead application. Under the lead stress conditions, application of both bacillus and P led to marked increases in the concentrations of total soluble and non-reducing sugars but the reducing sugars were decreased. In this respect, Kandil (1995) revealed that lead decreased total, soluble and non-soluble carbohydrates of wheat grains. Also, Ali (1982) found that 100-1000 ppm of lead as foliar application or soil treatment decreased the non-reducing sugars in some vegetable crops. The reduction in carbohydrate concentration as a result of lead treatment may be attributed to Pb causes a decrease in the photosynthetic pigments (Sengar and Pandey, 1996) and ribulose diphosphate carboxylase (the key enzyme for carbohydrates synthesis) which in turn in decreasing in all sugar fractions (Stibrova *et al.*, 1986).

As shown from the above mentioned results, adding bacillus bacteria or phosphorus as calcium superphosphate to the polluted and non polluted soils with lead significantly improved the chemical properties of carrot roots and that may be due to its promotion effect on growth and yield as well as vital roles in physiological and biochemical processes in plant. In this connection, Antipchuk *et al.* (1982) and Ali and Selim (1996) observed that inoculation of tomato plants with Azotobacter resulted in a rise in fruit sugars and vitamin C contents. Bagal *et al.* (1989) found that protein, sugars, ascorbic acid and mineral contents were significantly increased by increasing the rates of N, P and K application. Marschner (1995) stated that P is a component of RNA and DNA, therefore, it might be expected that P supply would have important effect on biosynthesis of many compounds e.g. sugars, proteins and hormones. Moreover, Bender *et al.* (1986) revealed that photosynthetic CO₂ fixation and assimilates translocation were considerably increased in plant with the optimum P supply in comparison with the low P level.

6. Lead concentration:

Data illustrated in Fig. (2&3) that Pb accumulated more in shoot than in root and reached about five times. In both shoot and root Pb concentration was dramatically increased with increasing the Pb rates in soils. At the highest level of Pb, the increase percentage in Pb accumulation in shoot reached about 900 and 985.4% in the presence of PbCl₂, about 433.3 and 448.9% in the presence of Pb(NO₃)₂, whereas in root reached about 85.7 and 115.5% in the presence of PbCl₂, while about 57.2 and 84.6% in the presence of Pb(NO₃)₂, if compared with its concentration in the control plants. This indicates that carrot plants prefer to Pb uptake in salt form PbCl₂ more than in form Pb(NO₃)₂. These results may be explained why the deleterious effect of lead chloride on most characters measured in shoots was more extremely. The obtained results are in agreement with some those obtained by Gaweda (1995 and 1997), Hooda *et al.* (1997) and Moftah (2000).

In the polluted lead soils with PbCl₂ at rates of 1000, 2000 and 4000 µg Pb/g soil, adding bacillus bacteria as bioremediant for lead ions led to a reduction in its concen. by about 50.1, 43.4 and 51.6% in shoot, and by about 44.6, 51.3 and 53.2% in root, respectively, whereas in the presence Pb(NO₃)₂ were about 32.3, 32.2 and 65.1% in shoot, 44.1, 42.4 and 49.8% in root, (Fig., 4). Regarding the effect of using P as a chemical agents for lead remediation, it was found that adding P to the contaminated soils with PbCl₂ at the same above mentioned rates reduced Pb concen. by about 62, 36.6 and 59.3% in shoot, about 48, 60.4 and 72.1% in root, whereas in the presence of Pb(NO₃)₂ the reductions were about 38.4, 53.8 and 55.8% in shoot, about 58.7, 47.9 and 54.2% in root (Fig., 4). These results pointed out that using the P was more useful for lead remediation and consequently overcome the toxicity effect of lead on carrot plant. The obtained results of bacillus-lead interaction are in accordance with those reported by Mahmoud and El-Beltagy (1998), who found that using bacillus bacteria strain No. 15 in the naturally lead-polluted soils reduced the lead uptake by 96.4% in the rocket salad plant, whereas the reduction was 73.49% in the soil polluted with 400 ppm lead. The reduction in lead accumulation as a result of using bacteria as bioremediants may be attributed to precipitation of metal ions, adsorption at bacterial sites and reduction by change of oxidation states (Ibeanusi *et al.*, 1995)

As for the P-lead interaction, Gaweda (1997) indicated that using phosphorurs (800 mg P/kg DW), calcium (1500 mg Ca/kg DW) and magnesium (240 mg/kg DW) as fertilizer or liming to increase soil pH from 5.1 to 6.2 considerably limited the accumulation of Pb in carrot roots.

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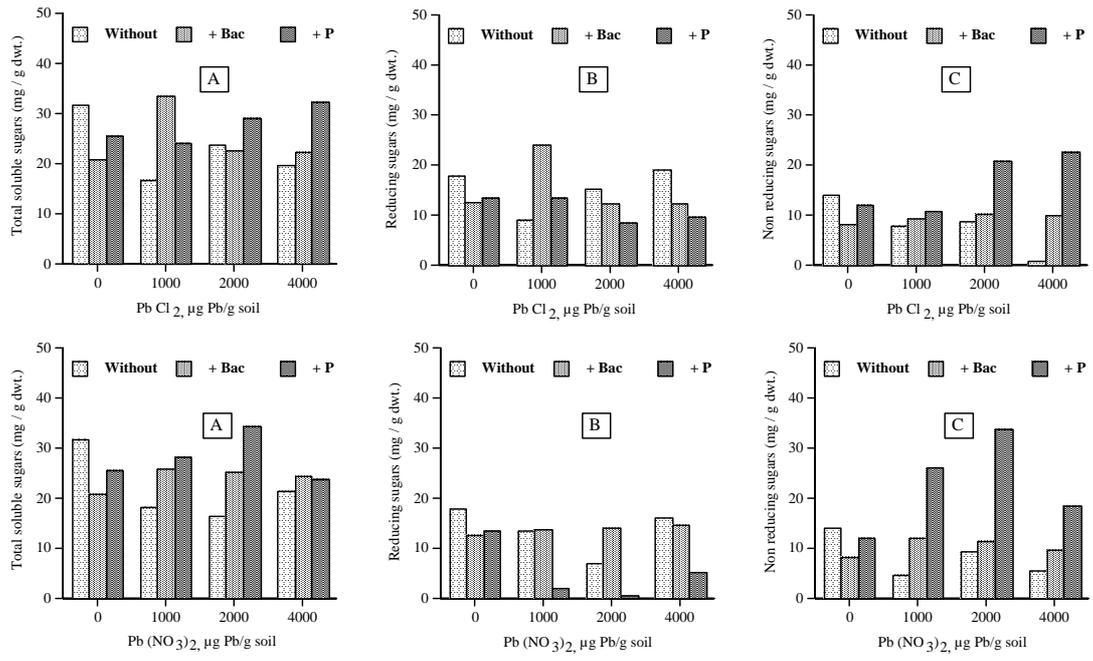


Fig. (1) : Effect of lead ($PbCl_2$ & $Pb(NO_3)_2$) and some agents, along with their interactions on the concentration of total soluble (A), reducing (B) and non-reducing (C) sugars in carrot root.

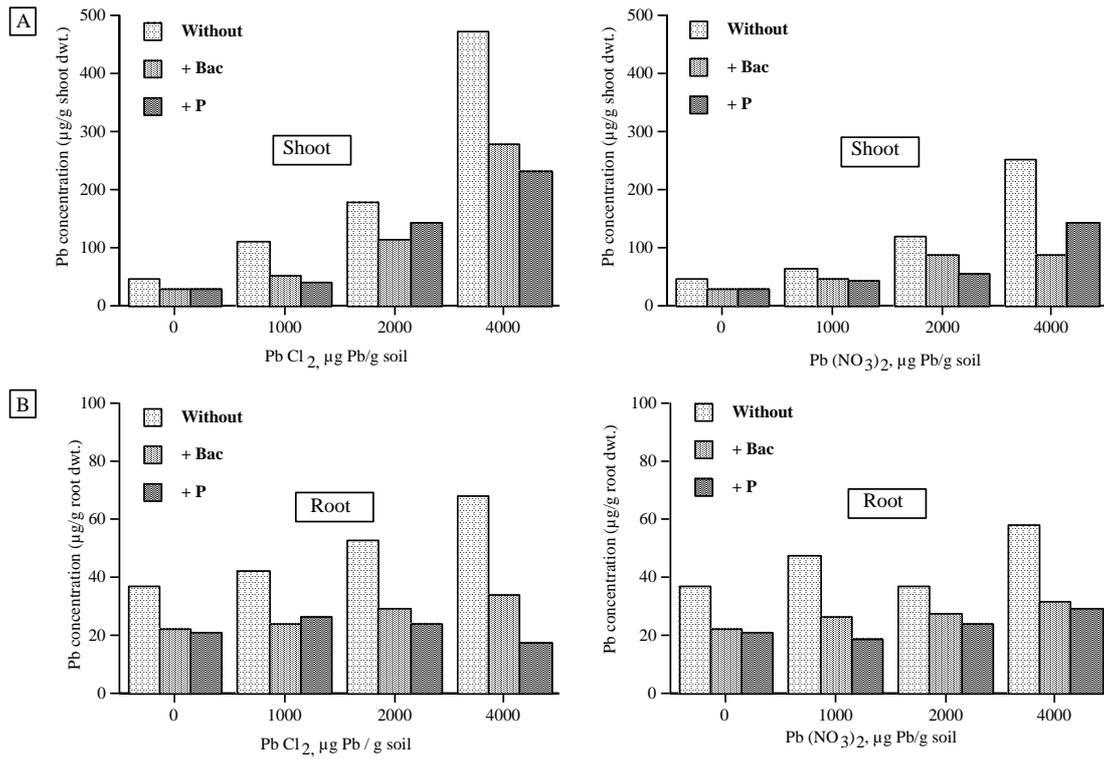


Fig. (2) : Effect of lead ($PbCl_2$ & $Pb(NO_3)_2$) and some agents, along with their interactions on Pb concentration in both shoot (A) and root (B) at 1998 / 1999 growing season.

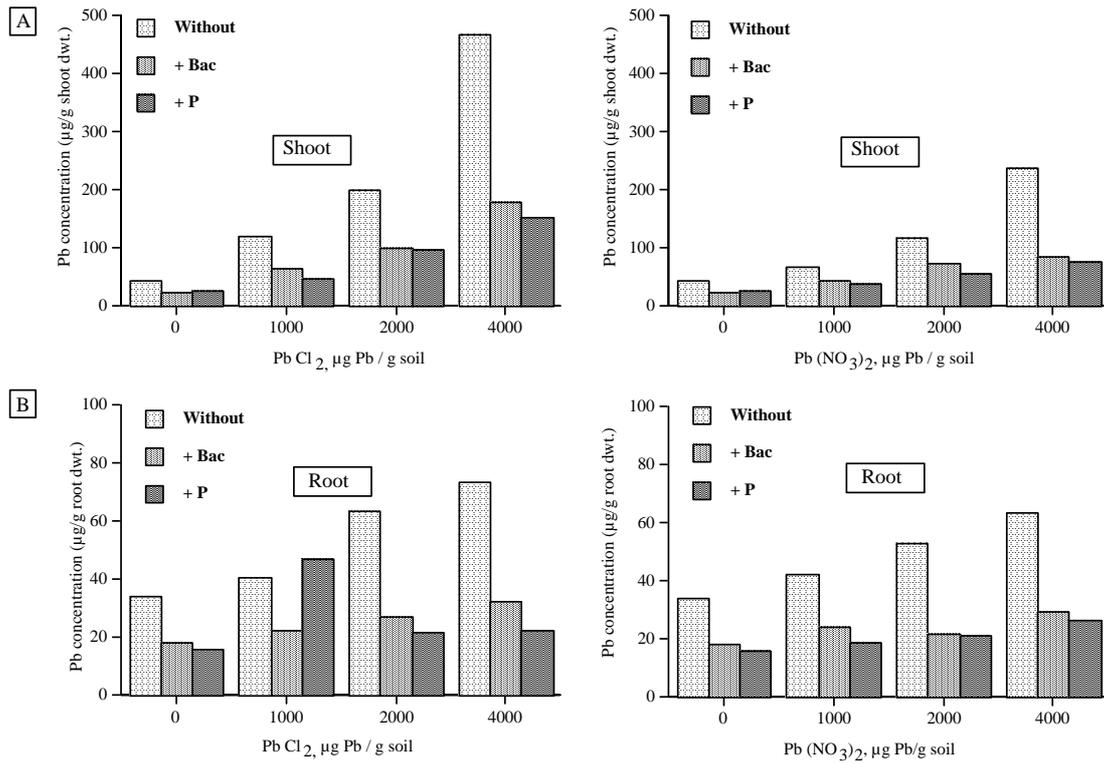


Fig. (3) : Effect of lead (PbCl_2 & $\text{Pb}(\text{NO}_3)_2$) and some agents, along with their interactions on Pb concentration in both shoot (A) and root (B) at 1999 / 2000 growing season.

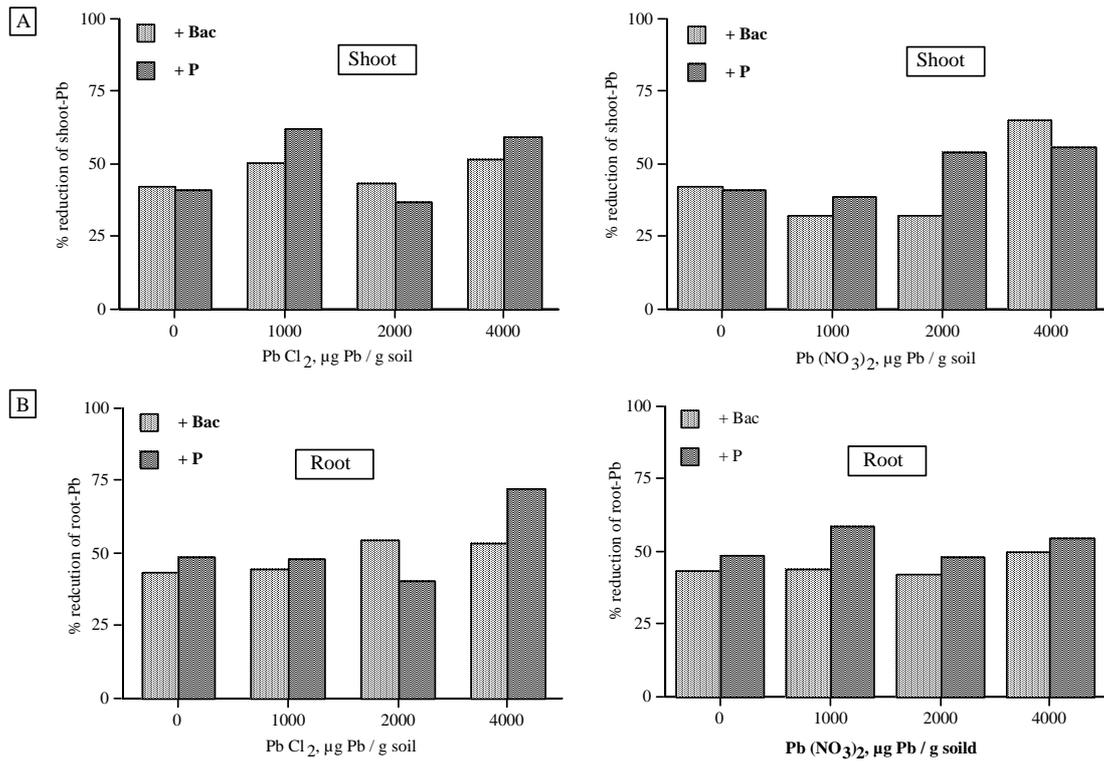


Fig. (4) : Effect of some agents on the percentage reduction of lead in both shoot (A) and root (B) (mean value of two seasons).

Table (1) : Effect of lead and some agents, along with their interactions, on some growth characters of carrot plant at 1999 / 2000 growing seasons.

Characters	Root length (cm)					Root diameter (cm)					Root size (cm ³)					Core diameter (cm)					Plant height (cm)						
	Agents					Agents					Agents					Agents					Agents						
	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2		
1998 / 1999																											
Pb Cl ₂	0000	7.65	7.10	9.10	7.38	8.38	2.58	2.63	3.11	2.61	2.85	40.01	38.59	69.16	39.30	54.58	1.25	1.72	1.79	1.49	1.52	39.35	42.28	39.10	40.81	39.23	
	1000	7.25	9.20	9.95	8.23	8.60	2.48	2.90	3.07	2.69	2.78	35.04	60.79	73.68	47.91	54.36	1.09	1.84	1.71	1.47	1.40	39.30	39.75	38.85	39.53	39.08	
	2000	7.60	9.10	8.62	8.35	8.11	2.14	2.88	2.70	2.51	2.42	27.35	59.30	49.37	43.33	38.36	0.94	1.57	1.60	1.26	1.27	31.13	31.15	33.20	31.14	32.17	
	4000	6.65	7.70	8.55	7.18	7.60	2.25	2.60	2.66	2.43	2.45	26.45	40.90	47.43	33.67	36.94	1.18	1.66	1.36	1.42	1.27	26.87	27.65	32.90	27.26	29.88	
	Mean	7.29	8.28	9.06			2.36	2.75	2.88			32.21	49.90	59.91			1.12	1.70	1.32			34.16	35.21	36.01			
Pb (NO ₃) ₂	0000	7.65	7.10	9.10	7.38	8.38	2.58	2.63	3.11	2.61	2.85	40.01	38.59	69.16	39.30	54.58	1.25	1.72	1.79	1.49	1.52	39.35	42.28	39.10	40.81	39.23	
	1000	7.55	7.7	8.15	7.63	7.85	2.27	2.71	2.61	2.49	2.44	30.57	44.43	43.66	37.50	37.11	1.38	1.67	1.47	1.53	1.43	33.75	37.13	38.50	35.44	36.13	
	2000	6.36	6.39	7.40	6.37	6.88	2.37	2.80	2.74	2.59	2.55	28.02	39.36	43.57	33.69	35.80	1.37	1.69	1.42	1.53	1.40	33.75	34.83	40.53	34.29	37.14	
	4000	5.70	6.80	6.71	6.25	6.21	2.16	2.63	2.64	2.40	2.40	20.90	36.96	36.70	28.93	28.80	1.33	1.51	1.27	1.42	1.30	25.48	31.40	31.03	28.44	28.25	
	Mean	6.81	7.00	7.84			2.35	2.69	2.77			29.87	39.83	48.27			1.33	1.65	1.49			33.08	36.41	37.29			
L.S.D. at 5% Pb Cl ₂ P ₁ =0.512 Bac.=0.362 P ₂ =0.346 P =0.245 P ₃ =0.483 P ₄ =0.483 P ₅ =0.483 Pb (NO ₃) ₂ P ₁ =0.108 Bac.=0.076 P ₂ =0.094 P =0.067 P ₃ =0.153 P ₄ =0.133 P ₅ =0.133																											
1999 / 2000																											
Pb Cl ₂	0000	8.00	8.14	9.86	8.07	8.93	2.71	2.74	3.23	2.73	2.97	46.25	47.93	80.55	47.09	63.40	1.39	1.78	1.88	1.58	1.63	37.73	43.17	40.87	40.45	39.30	
	1000	7.05	9.88	10.81	8.46	8.93	2.57	2.94	2.98	2.76	2.77	36.49	67.27	75.19	51.88	55.84	1.36	1.67	1.78	1.52	1.57	40.30	41.07	41.55	40.68	40.93	
	2000	6.42	9.75	9.53	8.08	7.97	2.14	2.92	2.80	2.53	2.47	23.18	65.42	58.70	44.30	40.94	1.04	1.31	1.62	1.18	1.33	29.05	31.65	34.60	30.35	31.83	
	4000	6.17	8.06	8.78	7.11	7.47	2.19	2.50	2.74	2.34	2.46	23.15	39.59	51.78	31.37	37.46	1.1	1.38	1.40	1.24	1.25	26.35	29.27	33.87	27.81	30.11	
	Mean	6.91	8.96	9.74			2.40	2.78	2.94			32.27	55.05	66.55			1.22	1.54	1.67			33.36	36.29	37.72			
Pb (NO ₃) ₂	0000	8.00	8.14	9.86	8.07	8.93	2.71	2.74	3.23	2.73	2.97	46.25	47.93	80.55	47.09	63.40	1.39	1.78	1.88	1.58	1.63	37.73	43.17	40.87	40.45	39.30	
	1000	7.13	7.89	8.57	7.51	7.85	2.25	2.46	2.90	2.36	2.58	28.34	37.62	56.64	32.98	42.49	1.25	1.74	1.54	1.50	1.40	33.30	37.67	38.83	35.48	36.07	
	2000	5.69	6.55	8.17	6.12	6.93	2.18	2.55	2.81	2.36	2.50	21.24	33.35	50.82	27.29	36.03	1.14	1.69	1.50	1.42	1.32	31.93	36.57	39.97	34.25	35.95	
	4000	5.25	7.00	7.10	6.13	6.18	1.99	2.41	2.70	2.20	2.34	16.27	31.94	40.67	24.10	28.47	1.21	1.54	1.41	1.38	1.31	27.10	27.30	32.97	27.20	30.03	
	Mean	6.52	7.39	8.42			2.28	2.54	2.91			28.02	37.71	57.17			1.25	1.69	1.58			32.52	36.18	38.16			
L.S.D. at 5% Pb Cl ₂ P ₁ =0.533 Bac.=0.377 P ₂ =0.425 P =0.301 P ₃ =0.602 P ₄ =0.753 P ₅ =0.602 Pb (NO ₃) ₂ P ₁ =0.446 Bac.=0.236 P ₂ =0.538 P =0.380 P ₃ =0.674 P ₄ =0.422 P ₅ =0.422																											

Table (1) : Cont.

Characters		Root dry wt. (g / plant)					Shoot dry wt. (g / plant)					Whole plant (g / plant)					Root / shoot ratio				
Treatments		Agents					Agents					Agents					Agents				
Pb salts	Pb ions (µg/g soil)	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2
1998 / 1999																					
Pb Cl ₂	0000	3.41	3.27	3.48	3.34	3.45	1.61	1.43	1.67	1.52	1.64	5.02	4.70	5.15	4.86	5.09	2.12	2.29	2.08	2.20	2.10
	1000	3.12	2.90	2.95	3.01	3.04	0.95	1.08	1.76	1.02	1.36	4.07	3.98	4.71	4.03	4.39	3.28	2.69	1.68	2.98	2.48
	2000	1.61	2.28	2.03	1.95	1.82	0.84	0.90	0.99	0.87	0.92	2.45	3.18	3.02	2.82	2.74	1.92	2.53	2.05	2.23	1.98
	4000	1.39	2.75	2.19	2.07	1.79	0.91	1.23	1.06	1.07	0.99	2.30	3.98	3.25	3.14	2.78	1.53	2.24	2.07	1.88	1.80
	Mean	2.38	2.80	2.66			1.08	1.16	1.37			3.46	3.96	4.03			2.21	2.44	1.97		
Pb (NO ₃) ₂	0000	3.41	3.27	3.48	3.34	3.45	1.61	1.43	1.67	1.52	1.64	5.02	4.70	5.15	4.86	5.09	2.12	2.29	2.08	2.20	2.10
	1000	1.50	1.98	2.55	1.74	2.03	1.01	1.18	1.03	1.10	1.02	2.51	3.16	3.58	2.84	3.05	1.49	1.68	2.48	1.58	1.98
	2000	1.15	1.85	2.51	1.50	1.83	1.06	1.42	1.38	1.24	1.22	2.21	3.27	3.89	2.74	3.03	1.08	1.30	1.82	1.19	1.45
	4000	1.06	1.38	1.56	1.22	1.31	0.94	0.67	1.04	0.81	0.99	2.00	2.05	2.60	2.03	2.30	1.13	2.06	1.50	1.59	1.31
	Mean	1.78	2.12	2.53			1.16	1.18	1.28			2.94	3.30	3.81			1.45	1.83	1.97		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.327 Pb2=0.227	Bac.=0.231 P =0.160	PbxBac.=0.463 PbxP =0.323			Pb1=0.065 Pb2=0.063	Bac.=0.046 P =0.044	PbxBac.=0.093 PbxP =0.089			Pb1=0.320 Pb2=0.186	Bac.=0.230 P =0.131	PbxBac.=0.453 PbxP =0.263			Pb1=0.232 Pb2=0.102	Bac.=0.164 P =0.072	PbxBac.=0.328 PbxP =0.144		
	Pb (NO ₃) ₂	Pb1=0.271 Pb2=0.263	Bac.=0.192 P =0.186	PbxBac.=0.384 PbxP =0.327			Pb1=0.070 Pb2=0.042	Bac.=N.S. P =0.030	PbxBac.=0.099 PbxP =0.059			Pb1=0.310 Pb2=0.425	Bac.=0.220 P =0.301	PbxBac.=0.436 PbxP =0.602			Pb1=0.188 Pb2=0.178	Bac.=0.133 P =0.126	PbxBac.=0.266 PbxP =0.254		
1999 / 2000																					
Pb Cl ₂	0000	1.78	2.62	3.50	2.20	2.64	1.02	1.34	1.89	1.18	1.46	2.80	3.96	5.39	3.38	4.10	1.75	1.96	1.85	1.58	1.80
	1000	2.48	3.50	2.56	2.99	2.52	1.72	1.36	1.55	1.54	1.64	4.20	4.86	4.11	4.53	4.16	1.44	2.57	1.65	2.01	1.55
	2000	1.60	2.41	2.43	2.01	2.02	1.09	1.01	1.15	1.05	1.12	2.69	3.42	3.58	3.06	3.14	1.47	2.39	2.11	1.93	1.79
	4000	1.20	2.74	3.04	1.97	2.12	0.94	1.89	1.19	1.42	1.07	2.14	4.63	4.23	3.38	3.18	1.27	1.45	2.55	1.36	1.91
	Mean	1.76	2.82	2.88			1.19	1.40	1.45			2.96	4.22	4.33			1.48	2.09	2.04		
Pb (NO ₃) ₂	0000	1.78	2.62	3.50	2.20	2.64	1.02	1.34	1.89	1.18	1.46	2.80	3.96	5.39	3.39	4.10	1.75	1.96	1.85	1.85	1.80
	1000	1.91	1.95	3.02	1.93	2.47	1.55	1.91	1.90	1.73	1.73	3.46	3.86	4.92	3.66	4.19	1.23	1.02	1.59	1.13	1.41
	2000	1.69	1.65	2.88	1.67	2.29	1.21	1.33	1.90	1.27	1.56	2.90	2.98	4.78	2.94	3.84	1.40	1.24	1.52	1.32	1.46
	4000	1.16	1.67	1.47	1.41	1.31	0.96	1.23	1.16	1.10	1.06	2.12	2.90	2.63	2.51	2.57	1.20	1.36	1.27	1.28	1.24
	Mean	1.63	1.97	2.72			1.19	1.45	1.71			2.82	3.43	4.43			1.39	1.39	1.56		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.225 Pb2=0.295	Bac.=0.159 P =0.208	PbxBac.=0.318 PbxP =0.418			Pb1=0.083 Pb2=0.077	Bac.=0.059 P =0.054	PbxBac.=0.117 PbxP =0.111			Pb1=0.406 Pb2=0.316	Bac.=0.287 P =0.223	PbxBac.=0.574 PbxP =0.447			Pb1=0.100 Pb2=N.S.	Bac.=0.071 P =0.238	PbxBac.=0.147 PbxP =0.476		
	Pb (NO ₃) ₂	Pb1=0.257 Pb2=0.195	Bac.=0.181 P =0.138	PbxBac.=0.363 PbxP =0.277			Pb1=0.165 Pb2=0.096	Bac.=0.117 P =0.068	PbxBac.=0.235 PbxP =0.136			Pb1=0.252 Pb2=0.435	Bac.=0.178 P =0.308	PbxBac.=0.363 PbxP =0.615			Pb1=0.087 Pb2=0.105	Bac.=N.S. P =0.074	PbxBac.=0.123 PbxP =0.149		

Table (2) : Effect of lead and some agents, along with their interactions on photosynthetic pigments (mg / g dw) in leaves of carrot plant at 1999 / 2000 growing seasons.

Characters		Chl. a					Chl. b					Carotenoids a + b					Chl. a + b				
Treatments		Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2
Pb salts	Pb ions (µg/g soil)	Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P		
1998 / 1999																					
Pb Cl ₂	0000	2.32	3.75	3.78	3.04	3.05	1.47	1.07	1.57	1.27	1.52	3.79	4.82	5.35	4.31	4.57	1.96	2.73	2.17	2.35	2.07
	1000	1.35	1.98	4.20	1.66	2.77	0.89	1.73	1.68	1.31	1.28	2.24	3.71	5.88	2.98	4.06	1.19	1.04	3.12	1.11	2.15
	2000	1.10	2.72	2.08	1.91	1.59	0.47	1.14	1.23	0.80	0.85	1.57	3.86	3.31	2.71	2.44	1.49	1.24	1.35	1.36	1.42
	4000	0.21	1.68	1.94	0.95	1.07	0.16	0.53	0.79	0.35	0.47	0.37	2.21	2.73	1.29	1.55	1.09	0.89	1.96	0.99	1.52
	Mean	1.24	2.53	3.00			0.75	1.12	1.32			1.99	3.65	4.32			1.43	1.47	2.15		
Pb (NO ₃) ₂	0000	2.32	3.75	3.78	3.04	3.05	1.47	1.07	1.57	1.27	1.52	3.79	4.82	5.35	4.31	4.57	1.96	2.73	2.17	2.35	2.07
	1000	1.34	2.49	2.66	1.91	2.00	1.17	1.12	1.95	1.15	1.56	2.51	3.61	4.61	3.06	3.56	1.13	1.67	1.45	1.40	1.29
	2000	1.61	1.54	2.56	1.57	2.09	1.00	0.98	1.05	0.99	1.03	2.61	2.52	3.61	2.56	3.11	1.32	1.10	1.72	1.21	1.52
	4000	0.78	1.07	1.17	0.93	0.98	0.68	0.99	1.06	0.83	0.87	1.46	2.06	2.23	1.76	1.84	0.38	1.02	1.64	0.70	1.01
	Mean	1.51	2.21	2.54			1.08	1.04	1.41			2.59	3.25	3.95			1.20	1.63	1.74		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.123 Pb2=0.097	Bac.=0.087 P =0.069	PbxBac.=0.173 PbXP =0.138	Pb1=0.060 Pb2=0.034	Bac.=0.040 P =0.024	PbxBac.=0.084 PbXP =0.153	Pb1=0.131 Pb2=0.193	Bac.=0.093 P =0.136	PbxBac.=0.185 PbXP =0.727	Pb1=0.120 Pb2=0.138	Bac.=N.S. P =0.098	PbxBac.=0.170 PbXP =0.196								
	Pb (NO ₃) ₂	Pb1=0.309 Pb2=0.337	Bac.=0.218 P =0.238	PbxBac.=0.436 PbXP =0.476	Pb1=0.096 Pb2=0.095	Bac.=N.S. P =0.067	PbxBac.=0.136 PbXP =0.135	Pb1=0.090 Pb2=0.291	Bac.=0.126 P =0.206	PbxBac.=0.179 PbXP =0.411	Pb1=0.067 Pb2=0.195	Bac.=0.047 P =0.138	PbxBac.=0.096 PbXP =0.276								
1999 / 2000																					
Pb Cl ₂	0000	2.98	4.57	4.44	3.78	3.71	1.72	1.72	2.42	1.72	2.07	4.70	6.29	6.86	5.50	5.78	1.68	2.32	2.99	2.00	2.34
	1000	2.22	3.33	3.72	2.78	2.97	1.72	1.78	1.54	1.72	1.63	3.94	5.11	5.26	4.49	4.60	1.08	1.86	2.02	1.47	1.55
	2000	1.00	1.63	1.94	1.32	1.47	0.42	1.33	1.36	0.88	0.89	1.42	2.96	3.30	2.19	2.36	1.34	1.28	1.31	1.31	1.32
	4000	0.12	0.80	1.44	0.46	0.78	0.16	0.33	0.89	0.24	0.53	0.28	1.13	2.33	0.70	1.31	1.07	1.09	1.45	1.08	1.26
	Mean	1.58	2.58	2.89			1.00	1.27	1.55			2.58	3.86	4.44			1.29	1.64	1.94		
Pb (NO ₃) ₂	0000	2.98	4.57	4.44	3.78	3.71	1.72	1.72	2.42	1.72	2.07	4.70	6.29	6.86	5.50	5.78	1.68	2.32	2.99	2.00	2.34
	1000	1.53	1.75	2.69	1.64	2.11	1.34	1.70	1.87	1.52	1.61	2.87	3.45	4.56	3.16	3.72	1.29	1.18	1.37	1.23	1.33
	2000	1.50	1.48	1.54	1.49	1.52	1.43	1.38	1.09	1.41	1.26	2.93	2.86	2.63	2.90	2.78	1.23	1.09	1.23	1.16	1.23
	4000	0.58	0.98	1.21	0.78	0.90	0.16	1.03	1.05	0.59	0.61	0.74	2.01	2.26	1.37	1.50	0.62	1.00	1.33	0.81	0.98
	Mean	1.65	2.20	2.47			1.16	1.46	1.61			2.81	3.65	4.08			1.20	1.40	1.73		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.241 Pb2=0.337	Bac.=0.170 P =0.238	PbxBac.=0.341 PbXP =0.429	Pb1=0.148 Pb2=0.168	Bac.=0.102 P =0.119	PbxBac.=0.205 PbXP =0.238	Pb1=0.469 Pb2=0.374	Bac.=0.153 P =0.264	PbxBac.=0.284 PbXP =0.528	Pb1=0.030 Pb2=0.042	Bac.=0.021 P =0.050	PbxBac.=0.042 PbXP =0.061								
	Pb (NO ₃) ₂	Pb1=0.342 Pb2=0.183	Bac.=0.242 P =0.130	PbxBac.=0.483 PbXP =0.259	Pb1=0.301 Pb2=0.080	Bac.=0.213 P =0.060	PbxBac.=0.425 PbXP =0.114	Pb1=0.211 Pb2=0.128	Bac.=0.149 P =0.090	PbxBac.=0.299 PbXP =0.184	Pb1=0.131 Pb2=0.149	Bac.=0.093 P =0.105	PbxBac.=0.185 PbXP =0.667								

Table (3) : Effect of lead and some agents, along with their interactions on leaf water relations of carrot plant at 1999 / 2000 growing seasons.

Characters		Total water content (%)					Relative water content (%)					Leaf water deficit (%)					Transpiration rate (mg H ₂ O / g Fwt. h)				
Treatments		Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2
Pb salts	Pb ions (µg/g soil)	Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P		
1998 / 1999																					
Pb Cl ₂	0000	82.53	85.54	82.07	84.04	82.30	82.18	88.23	87.90	85.21	85.04	17.82	11.77	12.10	14.79	14.96	39.74	27.45	27.12	33.59	33.43
	1000	81.10	82.75	80.15	81.92	80.62	83.30	83.41	86.94	83.35	85.12	16.70	16.59	13.06	16.65	14.88	40.36	29.59	36.52	34.98	38.44
	2000	77.50	70.81	89.09	74.16	83.29	63.90	86.30	89.55	75.10	76.72	36.10	13.70	10.45	24.90	23.28	60.25	47.21	32.62	53.73	46.44
	4000	79.69	78.21	88.25	78.95	83.97	70.25	75.27	81.05	72.76	75.65	29.75	24.73	18.95	27.24	24.35	61.57	50.65	35.35	56.11	48.46
	Mean	80.20	79.33	84.89			74.91	83.30	86.36			25.09	16.70	13.64			50.48	38.73	33.90		
Pb (NO ₃) ₂	0000	82.53	85.54	82.07	84.04	82.30	82.18	88.23	87.90	85.21	85.04	17.82	11.77	12.10	14.79	14.96	39.74	27.45	27.12	33.59	33.43
	1000	79.43	78.31	88.69	78.87	84.06	72.75	82.52	88.63	77.63	80.69	27.25	17.48	11.37	22.37	19.31	71.32	34.78	31.07	53.05	51.19
	2000	81.12	87.78	88.96	84.45	85.04	69.92	79.06	87.55	74.49	78.74	30.08	20.94	12.45	25.51	21.26	77.23	30.76	34.13	54.00	55.68
	4000	89.22	85.32	90.56	87.27	89.89	69.46	77.18	85.13	73.32	77.30	30.54	22.81	14.87	26.68	22.70	51.72	41.98	41.95	46.85	46.83
	Mean	83.07	84.24	87.57			73.58	81.75	87.30			26.42	18.25	12.70			60.00	33.74	33.57		
L.S.D. at 5%	Pb Cl ₂	Pb1=1.800 Pb2=1.046	Bac.=N.S. P =0.740	PxBac.=2.608 PxBP =1.480			Pb1=1.326 Pb2=2.497	Bac.=0.938 P =1.766	PxBac.=1.877 PxBP =0.453			Pb1=1.303 Pb2=0.635	Bac.=0.922 P =0.450	PxBac.=1.844 PxBP =0.898			Pb1=0.578 Pb2=1.900	Bac.=0.409 P =1.340	PxBac.=0.818 PxBP =2.684		
	Pb (NO ₃) ₂	Pb1=0.384 Pb2=0.685	Bac.=0.271 P =0.484	PxBac.=0.543 PxBP =0.969			Pb1=1.007 Pb2=1.978	Bac.=0.712 P =1.399	PxBac.=1.425 PxBP =2.798			Pb1=0.376 Pb2=2.535	Bac.=0.266 P =1.793	PxBac.=0.532 PxBP =3.586			Pb1=1.054 Pb2=1.146	Bac.=0.745 P =0.810	PxBac.=1.490 PxBP =1.620		
1999 / 2000																					
Pb Cl ₂	0000	84.60	78.09	70.12	81.35	77.36	81.83	78.47	83.82	80.15	82.83	18.17	21.53	16.18	19.85	17.17	48.97	19.76	38.82	34.37	43.90
	1000	75.82	77.00	82.78	76.41	79.30	67.74	81.64	90.00	74.69	78.87	32.26	18.36	10.00	25.31	21.13	52.63	33.66	31.84	43.15	42.23
	2000	76.52	71.18	89.27	73.85	82.90	74.85	87.43	88.02	81.14	81.43	25.15	12.57	11.98	18.86	18.57	53.03	42.01	46.39	47.52	49.71
	4000	83.22	77.33	89.38	80.28	86.30	72.87	77.67	84.50	75.27	78.68	27.13	22.33	15.50	24.37	21.32	61.67	44.04	36.11	52.85	48.89
	Mean	80.04	75.90	82.89			74.32	81.30	86.58			25.68	18.70	13.42			54.08	34.87	38.29		
Pb (NO ₃) ₂	0000	84.60	78.09	70.12	81.35	77.36	81.83	78.47	83.82	80.15	82.83	18.17	21.53	16.18	19.85	17.17	48.97	19.76	38.82	34.37	43.90
	1000	83.68	79.95	88.54	91.81	86.11	67.43	74.29	88.75	70.86	78.08	32.57	25.71	11.27	29.14	21.92	46.85	34.98	54.63	40.92	50.74
	2000	85.82	86.01	91.52	85.91	88.67	71.80	83.29	88.50	77.55	80.15	28.20	16.71	11.50	22.45	19.85	65.79	38.00	34.58	51.90	50.18
	4000	90.86	86.38	89.76	88.62	90.31	71.51	80.33	85.70	75.92	78.60	28.49	19.67	14.30	24.08	21.40	77.48	51.74	34.91	64.61	56.19
	Mean	86.24	82.61	84.98			73.14	79.09	86.69			26.86	20.91	13.31			59.77	36.12	40.73		
L.S.D. at 5%	Pb Cl ₂	Pb1=1.760 Pb2=1.978	Bac.=2.743 P =1.399	PxBac.=2.486 PxBP =2.798			Pb1=2.620 Pb2=2.337	Bac.=1.850 P =1.653	PxBac.=3.700 PxBP =3.305			Pb1=1.098 Pb2=1.139	Bac.=0.776 P =0.806	PxBac.=1.552 PxBP =1.611			Pb1=1.336 Pb2=2.999	Bac.=0.944 P =2.120	PxBac.=1.889 PxBP =4.241		
	Pb (NO ₃) ₂	Pb1=1.361 Pb2=1.743	Bac.=0.962 P =1.233	PxBac.=1.925 PxBP =2.466			Pb1=0.865 Pb2=1.363	Bac.=0.612 P =0.964	PxBac.=1.223 PxBP =1.927			Pb1=2.628 Pb2=1.633	Bac.=1.858 P =1.155	PxBac.=3.716 PxBP =2.309			Pb1=0.819 Pb2=1.919	Bac.=0.579 P =1.357	PxBac.=1.159 PxBP =2.714		

Table (4) : Effect of lead and some agents, along with their interactions on yield and harvest index of carrot plant at 1999 / 2000 growing seasons.

Characters		Root yield (kg / m ²)					Top yield (kg / m ²)					Total yield (kg / m ²)					Harvest index (%)					
Treatments		Agents					Agents					Agents					Agents					
Pb salts	Pb ions (µg/g soil)	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	Without	+Bac.	+P	Mean 1	Mean 2	
1998 / 1999																						
Pb Cl ₂	0000	3.56	4.47	4.55	4.02	4.06	1.58	1.97	2.32	1.78	1.95	5.14	6.44	6.87	5.79	6.01	69.26	69.41	66.23	69.34	67.75	
	1000	2.36	3.27	4.43	2.82	3.40	1.33	1.35	3.10	1.34	2.22	3.69	4.62	7.53	4.16	5.61	63.96	70.78	58.83	67.37	61.39	
	2000	1.81	2.79	3.84	2.30	2.83	0.93	1.71	2.54	1.32	1.74	2.74	4.50	6.38	3.62	4.56	66.06	62.00	60.19	64.03	63.12	
	4000	1.56	2.03	3.22	1.80	2.39	0.92	1.25	1.73	1.09	1.33	2.48	3.28	4.95	2.88	3.72	62.90	61.89	65.05	62.40	63.98	
	Mean	2.32	3.14	4.01			1.19	1.57	2.42			3.51	4.71	6.43			65.54	66.02	62.57			
Pb (NO ₃) ₂	0000	3.56	4.47	4.55	4.02	4.06	1.58	1.97	2.32	1.78	1.95	5.14	6.44	6.87	5.79	6.01	69.26	69.41	66.23	69.34	67.75	
	1000	2.03	3.22	3.67	2.63	2.85	1.00	1.90	1.61	1.45	1.31	3.03	5.12	5.28	4.08	4.16	67.00	62.89	69.51	64.94	68.25	
	2000	1.71	2.47	3.06	2.09	2.39	1.54	1.59	2.26	1.57	1.90	3.25	4.06	5.32	3.66	4.29	52.62	60.84	57.52	56.73	55.07	
	4000	1.93	2.19	2.12	2.06	2.03	1.42	1.60	1.40	1.51	1.41	3.35	3.79	3.52	3.57	3.44	57.61	57.78	60.23	57.70	58.92	
	Mean	2.31	3.09	3.35			1.39	1.77	1.90			3.69	4.85	5.25			61.62	62.73	63.37			
L.S.D. at 5%	Pb Cl ₂	Pb1=0.031 Pb2=0.315	Bac=0.022 P =0.223	PxBac=0.044 PxBP =0.447			Pb1=0.183 Pb2=0.097	Bac=0.130 P =0.069	PxBac=0.266 PxBP =0.138			Pb1=0.222 Pb2=0.370	Bac=0.157 P =0.261	PxBac=0.313 PxBP =0.522			Pb1=0.523 Pb2=2.440	Bac=0.370 P =1.730	PxBac=0.741 PxBP =3.451			
	Pb (NO ₃) ₂	Pb1=0.125 Pb2=0.341	Bac=0.088 P =0.241	PxBac=0.175 PxBP =0.483			Pb1=0.088 Pb2=0.179	Bac=0.062 P =0.127	PxBac=0.124 PxBP =0.254			Pb1=0.182 Pb2=0.354	Bac=0.129 P =0.248	PxBac=0.257 PxBP =0.523			Pb1=0.720 Pb2=1.719	Bac=0.509 P =1.216	PxBac=1.018 PxBP =2.431			
	1999 / 2000																					
	Pb Cl ₂	0000	3.29	3.71	4.61	3.50	3.95	1.51	1.66	1.49	1.59	1.50	4.80	5.37	6.10	5.09	5.45	68.54	69.09	75.57	68.81	72.06
1000		2.87	3.25	3.70	3.06	3.29	1.61	1.33	1.18	1.47	1.40	4.48	4.58	4.88	4.53	4.68	64.06	70.96	75.82	67.51	69.94	
2000		1.43	3.09	2.05	2.26	1.74	1.19	1.23	1.36	1.21	1.28	2.62	4.32	3.41	3.47	3.02	54.58	71.53	60.12	63.05	57.35	
4000		1.41	2.43	2.33	1.92	1.87	1.00	1.00	1.25	1.00	1.13	2.41	3.43	3.58	2.92	3.00	58.51	70.85	65.08	64.68	61.80	
	Mean	2.25	3.12	3.17			1.33	1.31	1.32			3.58	4.43	4.49			61.42	70.61	69.15			
Pb (NO ₃) ₂	0000	3.29	3.71	4.61	3.50	3.95	1.51	1.66	1.49	1.59	1.50	4.80	5.37	6.10	5.09	5.45	68.54	69.09	75.57	68.81	72.06	
	1000	2.79	2.98	2.87	2.89	2.83	1.39	1.73	1.23	1.55	1.30	4.16	4.71	4.10	4.44	4.13	67.07	63.27	70.00	65.17	68.53	
	2000	2.00	1.57	2.61	1.79	2.31	1.77	1.66	1.76	1.72	1.77	3.77	3.23	4.37	3.50	4.07	53.05	48.61	59.73	50.83	56.39	
	4000	1.38	2.69	2.22	2.04	1.80	1.22	1.26	1.48	1.24	1.35	2.60	3.95	3.70	3.28	3.15	53.08	68.10	60.00	60.59	56.54	
	Mean	2.37	2.74	3.08			1.47	1.58	1.49			3.83	4.32	4.57			60.43	62.27	66.32			
L.S.D. at 5%	Pb Cl ₂	Pb1=0.171 Pb2=0.251	Bac=0.121 P =0.177	PxBac=0.241 PxBP =0.355			Pb1=0.098 Pb2=0.173	Bac=0.069 P =0.122	PxBac=0.139 PxBP =0.245			Pb1=0.336 Pb2=0.250	Bac=0.238 P =0.177	PxBac=0.476 PxBP =0.355			Pb1=1.792 Pb2=2.189	Bac=1.267 P =1.548	PxBac=2.534 PxBP =3.096			
	Pb (NO ₃) ₂	Pb1=0.431 Pb2=0.217	Bac=0.305 P =0.153	PxBac=0.609 PxBP =0.308			Pb1=0.133 Pb2=0.078	Bac=0.080 P =N.S.	PxBac=0.160 PxBP =0.111			Pb1=0.348 Pb2=0.477	Bac=0.246 P =0.337	PxBac=0.492 PxBP =0.674			Pb1=1.696 Pb2=1.154	Bac=1.200 P =0.816	PxBac=2.399 PxBP =1.633			

Table (5) : Effect of lead and some agents, along with their interactions on some chemical properties of carrot root 1999 / 2000 growing seasons.

Characters		Total soluble solids (%)					Carotene (mg / 100 g fwt.)					Vit. A (IU / 100 g Fwt.)					Vit. C (mg / 100 g Fwt.)				
Treatments		Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2	Agents			Mean 1	Mean 2
Pb salts	Pb ions (µg/g soil)	Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P			Without	+Bac.	+P		
1998 / 1999																					
Pb Cl ₂	0000	10.95	14.09	12.29	12.52	11.62	3.05	4.26	3.64	3.65	3.35	6264.10	7203.72	6399.54	6733.91	6331.82	14.91	16.94	16.47	15.92	15.69
	1000	13.32	10.82	10.78	12.07	12.05	3.70	3.18	2.97	3.44	3.34	6238.71	6375.28	6378.21	6306.99	6308.46	11.87	10.22	12.47	11.05	12.17
	2000	13.33	10.01	12.45	11.67	12.89	2.69	3.08	4.05	2.88	3.37	5163.65	5214.44	6856.65	5189.05	6010.15	12.34	9.49	14.57	10.91	13.45
	4000	11.36	10.08	11.91	10.72	11.63	1.77	2.77	3.28	2.27	2.52	4681.15	4699.61	5544.58	4690.38	5112.86	10.93	7.28	12.45	9.05	11.64
	Mean	12.24	11.25	11.86			2.80	3.32	3.48			5586.90	5873.26	6294.74			12.49	10.98	13.99		
Pb (NO ₃) ₂	0000	10.95	14.09	12.29	12.52	11.62	3.05	4.26	3.64	3.65	3.35	6264.10	7203.72	6399.54	6733.91	6213.31	14.91	16.94	16.47	15.92	15.69
	1000	12.16	11.08	11.95	11.62	12.05	3.46	3.39	3.62	3.43	3.54	5857.63	5739.27	6120.20	5798.45	5988.91	10.70	10.84	13.07	10.77	11.8
	2000	12.15	13.17	12.38	12.66	12.26	2.53	3.95	3.58	3.24	3.55	5967.83	6687.35	6052.48	6327.59	6010.15	12.26	14.19	13.28	13.22	12.77
	4000	14.11	13.95	10.71	14.03	12.41	2.08	4.19	3.10	3.63	3.09	5163.65	7085.21	5239.81	6124.43	5201.74	7.60	16.70	9.68	12.15	8.64
	Mean	12.34	13.07	11.83			3.03	3.95	3.48			5813.30	6678.89	5953.76			11.37	14.66	13.12		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.465 Pb2=0.510	Bac=0.329 P =0.361	PbxBac=0.658 PbxP =0.722			Pb1=0.271 Pb2=0.304	Bac=0.192 P =0.215	PbxBac=0.384 PbxP =0.429			Pb1=128.09 Pb2= 38.54	Bac=90.57 P =27.25	PbxBac=180.736 PbxP = 54.490			Pb1=0.431 Pb2=0.370	Bac=0.305 P =0.260	PbxBac=0.612 PbxP =0.525		
	Pb (NO ₃) ₂	Pb1=0.089 Pb2=0.309	Bac=0.063 P =0.219	PbxBac=0.126 PbxP =0.437			Pb1=0.221 Pb2=0.313	Bac=0.156 P =0.221	PbxBac=0.313 PbxP =0.443			Pb1=120.87 Pb2=112.39	Bac=58.47 P =79.47	PbxBac=170.957 PbxP =163.304			Pb1=0.429 Pb2=0.346	Bac=0.303 P =0.245	PbxBac=0.607 PbxP =0.489		
1999 / 2000																					
Pb Cl ₂	0000	11.21	14.21	12.43	12.71	11.82	3.15	4.31	3.78	3.73	3.47	6772.00	7110.60	7150.02	6941.30	6961.01	13.55	16.26	12.75	14.91	13.15
	1000	13.85	11.25	11.21	12.55	12.53	3.82	3.30	3.00	3.56	3.41	6094.80	6330.78	7079.00	6212.79	6586.90	10.39	10.50	12.19	10.45	11.29
	2000	13.73	10.30	13.85	12.02	13.79	2.59	3.16	4.25	2.88	3.42	6077.87	6174.94	7195.25	6126.41	6636.56	11.61	10.84	16.65	11.23	14.13
	4000	11.77	10.20	13.45	10.99	12.61	1.48	3.11	3.30	2.30	2.39	4198.64	5285.23	5586.90	4741.94	4892.77	9.48	9.94	13.90	9.71	11.19
	Mean	12.64	11.49	12.74			2.76	3.47	3.58			5785.83	6225.39	6752.79			11.26	11.89	13.62		
Pb (NO ₃) ₂	0000	11.21	14.21	12.43	12.71	11.82	3.15	4.31	3.78	3.73	3.47	6772.00	7110.60	7150.02	6941.30	6961.01	13.55	16.12	12.75	14.91	13.15
	1000	13.33	13.50	12.00	12.92	12.17	2.25	3.45	3.81	3.35	3.53	5502.25	7100.21	7025.03	6301.23	6263.64	10.40	12.19	14.52	11.30	12.46
	2000	13.30	13.74	12.75	13.02	12.53	2.42	4.00	3.65	3.21	3.04	5756.20	6602.70	6852.58	6179.45	6304.39	11.61	15.48	13.55	13.55	12.58
	4000	14.21	14.00	11.20	14.11	12.71	2.85	4.22	3.19	3.54	3.02	5332.95	5719.21	5839.50	5526.11	5586.23	10.08	15.97	10.32	13.03	10.20
	Mean	12.51	13.86	12.10			2.92	4.00	3.61			5840.85	6633.20	6716.78			11.41	14.98	13.79		
L.S.D. at 5%	Pb Cl ₂	Pb1=0.534 Pb2=0.423	Bac=0.377 P =N.S.	PbxBac=0.755 PbxP =0.599			Pb1=0.128 Pb2=0.238	Bac=0.090 P =0.168	PbxBac=0.184 PbxP =0.336			Pb1= 44.13 Pb2= 92.16	Bac= 31.21 P = 65.17	PbxBac= 62.415 PbxP =130.346			Pb1=0.364 Pb2=0.429	Bac=0.258 P =0.303	PbxBac=0.517 PbxP =0.607		
	Pb (NO ₃) ₂	Pb1=0.361 Pb2=0.428	Bac=0.256 P =0.303	PbxBac=0.511 PbxP =0.607			Pb1=N.S. Pb2=0.387	Bac=0.287 P =0.274	PbxBac=0.567 PbxP =0.548			Pb1=205.00 Pb2= 65.65	Bac=144.96 P = 46.42	PbxBac=289.941 PbxP = 92.854			Pb1=0.433 Pb2=0.253	Bac=0.306 P =0.179	PbxBac=0.612 PbxP =0.359		