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Lead Uptake and Accumulation in Groundnut Crop Grown at Different Soil Lead Amendments

Lakshmi N.
Dept. of Environmental Sciences, Pragati Engineering College, ADB Road, Surampalem, 533437, Andhra Pradesh, INDIA

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Abstract

The present study deals with lead (Pb) uptake and accumulation in groundnut (Arachis hypogea L.var TMV-2).Pot experiments were conducted taking native agricultural soil spiked with Lead Nitrate to get 10.2.µg/g, 102 µg/g and 1020 µg/g and growing the groundnut species at these test concentrations along with control soil. Lead uptake and accumulation in different plants of root, stem, leaf, seed and whole plant were studies at different time intervals of crop ages of 30 days, 60 days and 90 days at different soil lead (Test) concentrations in comparisons with control soil.

Keywords: Lead uptake and accumulation in plants, lead toxicity in plants, heavy metal pollution in soils and plants.

Introduction

Trace elements released from various anthropogenic activities have entered agricultural systems at alarming levels causing a serious risk to the quality of production and quality of life. Of these, heavy metal contamination of soils has become a major problem in numerous areas of the world[1].

Lead (Pb) is a toxic heavy metal contaminating soils, including agricultural soils through various sources and by different means mining and smelting wastes, fly ash and sludge amendments, fertilizer and pesticidal applications, vehicular emissions and traffic water pipelines, paints etc. are some of the well known sources of Pb contamination.

Lead is not only a toxic element but also can be accumulated in plant organs and agricultural products[2,3], consequently enter human food chain[4]. As a result of consumption of food, lead accumulates in human body and it may cause renal failure, brain and liver damage and it can attack the nervous system and cause falling of sickness[5,6].

Lead is one of the most difficult pollutants to control. Environmental contamination with lead has accelerated due to its close relationship to industrialization and its wide usage in paints and gasoline. Lead (Pb) is one of the prominent examples for anthropogenic environmental metal pollution that originates from various activities including mining and smelting of lead-ores, burning of coal, effluents from storage battery industries, automobile exhausts, metal planting and finishing operations, fertilizers, pesticides and from additives in pigments and gasoline[7]. Soils contaminated with Pb cause sharp decreases in crop productivity thereby posing a serious problem for agriculture[8]. Although Pb is not an essential nutrient for plants, majority of lead is easily taken up by plants from the soil and accumulated in root while only a small fraction was translocated upward to the shoots[9].

Certain trace elements are essential in plant nutrition (micronutrients) but plants growing in a polluted environment can accumulate trace elements at high concentrations, causing a serious risk to human health when plant based food stuffs are consumed[10]. Being at the bottom of many of the natural food chains, metal accumulating plants are directly or indirectly responsible for a large proportion of dietary uptake of toxic heavy metals by humans and other animals[11]. Accumulation of Pb in food crops is receiving a great deal of attention in two ways: i. by its phytotoxicity and ii. its introduction in to the human food chain.Lead is extremely toxic to all intermediates of food chains[12] and human beings[13]. It has been reported that plants could accumulate considerable amount of toxic metals due to mechanism of tolerance[14].

Several studies related to heavy metal uptake by plants grown in polluted soils have shown that elevated levels of metals in soil may lead to increased uptake by plants but, without a strong relationship between the concentrations in soil and plants[10]. The increased uptake by plants may sometimes produce toxic effects in plants and also to its consumers.

The level of Pb which causes toxicity in plants is difficult to establish but it is generally agreed that soil Pb concentrations of 100 – 500 mg/g are considered to be excessive[11]. Further more, phytotoxicity is often species and environment specific. Thus studies on Pb uptake by agricultural crops assume greater importance especially in the regions where such contamination of soils and agricultural fields is a possibility.

So the present experimental studies are made to study the effect of lead contamination in agricultural soils on groundnut which is a widely grown edible oil seed crop in India which is leading in oil seed map both in production and acreage. Seeds of this crop are taken as food and also for oil extractions. Oil cake, and vegetative parts of the plant are used as feed for the cattle. Thus lead uptake and accumulations studies were carried out in Groundnut (*Arachis hypogea* var TMV-2).

Material and Methods

Pot experimental studies were carried on Groundnut crop (Arachis hypogea var TMV-2) using a native suitable soils of sandy loam type, soil in pots is homogenized with lead nitrate solution of different test concentrations of 10.2 µg/g, 102 µg/g and 1020 µg/g. Besides the test concentrations, a control which is unamended is also maintained. Test crop seeds are sown in pots at distances and depth specified by ICAR[15].

Chemical Analyses of plant material were conducted on crop on 30th, 60th, and 90th day to find the lead uptake and accumulation. Plant specimens were harvested, washed with distilled water, cut in to parts and dried in oven, and the dry weight is recorded for whole plant, root, stem, leaves and seeds. Oven dried plant material was ground to powder, and subjected to acid digestion to prepare sample solution following the methods of Robinson[16]. Lead content is quantified by AAS (Perkin Elmer 3110).

Soil: A red sandy loam soil is collected from agricultural field around vizag for pot experimental studies on groundnut. Soil is dried for 72 hours powdered to pass through 2 mm sieve and subjected to physico chemical analysis and characterization.

Seeds: Seeds of groundnut crop are collected from Agricultural Research Station of Andhra Pradesh located at Anakapalle, A.P.

Lead Nitrate: Soils are spiked with lead nitrate of Analytical grade (Qualigens) with mol.wt 331.21.

Pot Experimentation: Detailed investigations were carried out on groundnut species (Arachis hypogeal L. var TMV-2) in the experimental farm of Andhra University. Soil was spiked with Lead nitrate to different test concentrations 10.2 µg/g, 102µg/g , 1020µg/g in addition to control which is not spiked. 6 kg of soil was used in each pot having dimension 1ft X 1ft X 1ft. The soil in each pot is homogenized with lead nitrate solution and left for 2 days for stabilization.

Seeds of test species were sown in the pots at the distances and depth as described by ICAR [15]. 3 seedlings were maintained in each pot after 2 weeks of sowing. Experimental potted plants were grown under net house covered with transparent polythene sheet to protect them from rain water leaching, but kept open to air and ambient temperatures. The experiments were designed to harvest the plants three times at 30 days interval i.e on 30th, 60th, 90th day of crop age.

Estimation of Available Lead in soil: From the air dried, sieved soil, 5g samples were weighed and transferred in to 150ml polythene container followed by addition of 50 ml Ammonium acetate to each container. Samples were gently agitated (75 rpm) for 24 hrs, filtered through Whatman No 41 paper and stored in polythene bottles. Ammonium Acetate was choosen for the experiment because of its well proven use as a measure of plant available fraction of soil [17].

Lead is estimated in the solution after pre concentration technique of APDC and MIBK extraction and Atomic Absorption Spectrophotometer (Perkin Elmer 3110)

Estimation of Total Lead in Soil: Soil samples were dried at 50^{o}C and sieved to 2 mm size and 0.2 g accurately weighed sample is then transferred in to boiling tubes. 10 ml Conc HNO_3 is added, boiled to 3 ml and further 10 ml Conc HCl was added and then boiled to 3 ml. The solution was then diluted to 100 ml with DDW, and Lead is estimated by Atomic Absorption Spectrophotometer.

Estimation of Lead in Plants: The harvested plants were taken in the laboratory, washed with de ionized double distilled water (DDW), separated in to roots, stem and leaf and whole plants dried in oven at 65^{o}C for 72 hrs. The dried material were ground and kept in desiccators. These materials were used for chemical analysis. Lead content in plant material was determined as per methods prescribed by Robinson[16] et al.

From the plant material 0.2g was accurately weighed and transferred in to a set of boiling tubes.10 ml of concentrated $HNO_3$was added to each tube and mixture were heated on heating block until a final volume of 3ml was reached. Then 10 ml of conc. HCl was added to this and boiled to 3 ml.The samples were then diluted to 50 ml using DDW, and stored in plastic containers. Lead in sample solution was quantified using Atomic Absorption Spectrophotometer (Perkin Elmer 3110).

Results and Discussion

The whole plant soil used for experiment is having back ground levels of 18.5 µg/g total lead and 1.02 µg/g available lead.

Chemical analysis of plant materials was carried out to study the lead uptake in plant and accumulation in plant parts of roof, stem, leaf, and seed. The results were tabulated.

Table-1
Plant lead uptake (µg/plant) in various test concentrations and on different harvest days

Harvest day	Plant Pb Uptake (µg/Plant)			
	C	TC_1	TC_2	TC_3
Day-30	38.066	40.680	67.189	146.858
Day-60	85.599	101.608	130.233	503.191
Day-90	224.371	309.294	424.526	1087.873

Table-2
Root lead accumulation (µg/Plant) in various test concentration in different harvest days

Harvest day	**Root Pb - Accumulation (µg/Plant)**			
	C	**TC_1**	**TC_2**	**TC_3**
Day-30	8.271	12.87	22.749	93.327
Day-60	18.293	23.153	62.252	342.523
Day-90	47.524	71.779	255.078	689.64

Table-3
Stem-Pb Accumulation (µg/Plant) in different test concentrations on different harvest days

Harvest day	**Stem – Pb accumulation(µg/Plant)**			
	C	**TC_1**	**TC_2**	**TC_3**
Day-30	8.374	8.008	17.253	32.887
Day-60	18.058	18.143	26.093	120.060
Day-90	104.619	78.157	59.332	190.988

Table-4
Leaf - Pb Accumulation (µg/plant) in different test connections and on different harvest days

Harvest day	**Leaf - Pb accumulation (µg/Plant)**			
	C	**TC_1**	**TC_2**	**TC_3**
Day-30	21.442	16.874	27.187	20.306
Day-60	49.248	37.474	41.888	40.608
Day-90	72.228	60.976	67.316	170.240

Table-5
Seed lead accumulation (µg/plant) in different test concentrate on final harvest

Test Concentrations	**Seed – Pb Accumulation(µg/plant)**
C	0.0
TC_1	6.15
TC_2	42.8
TC_3	37.0

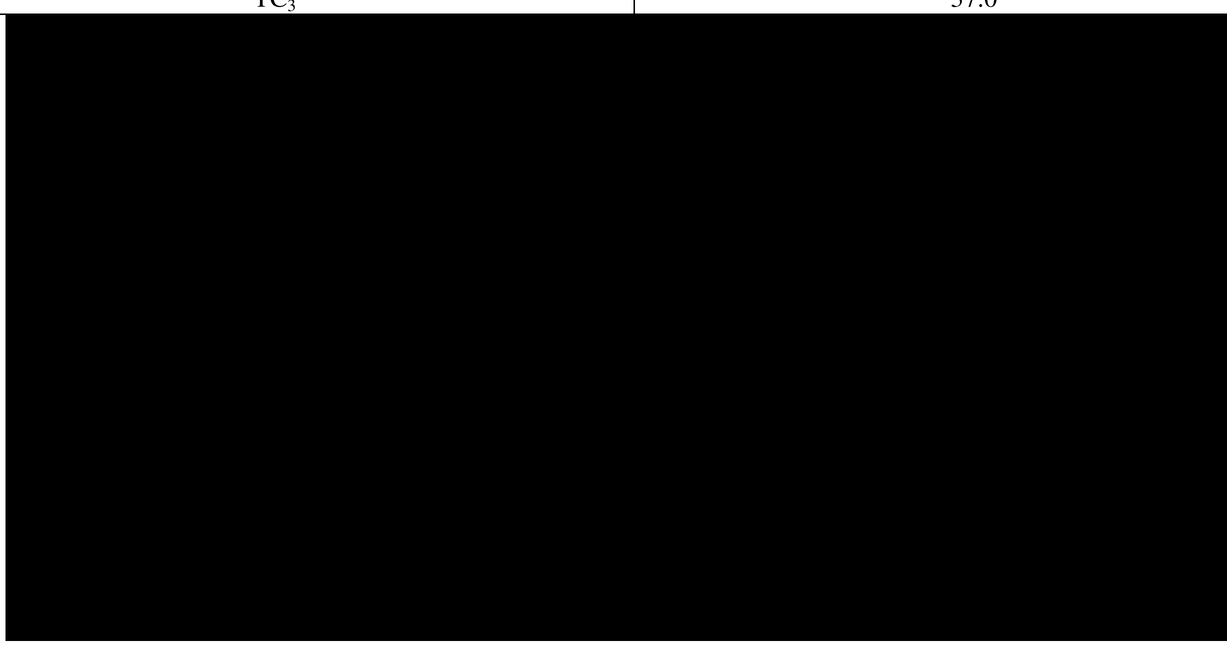

Figure-1
Plant lead uptake on different days of harvest

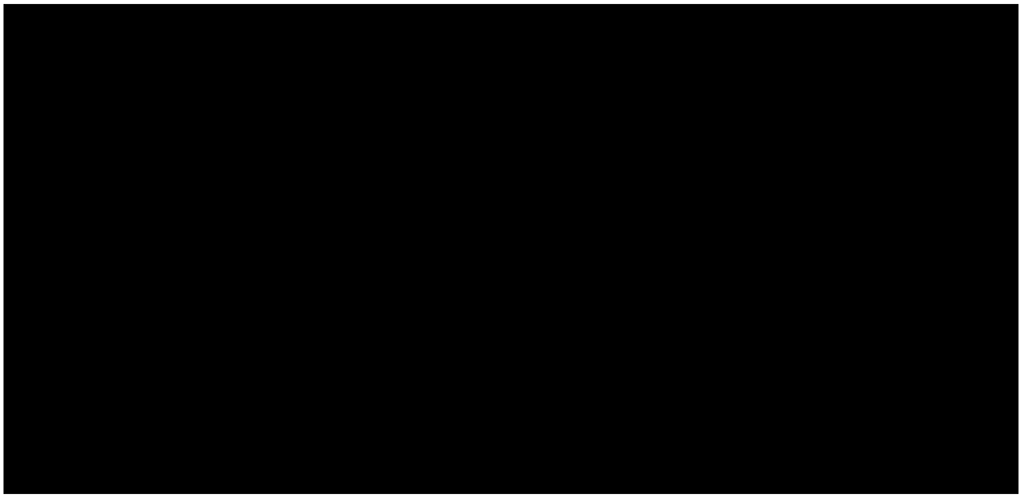

Figure-2
Lead accumulation in roots

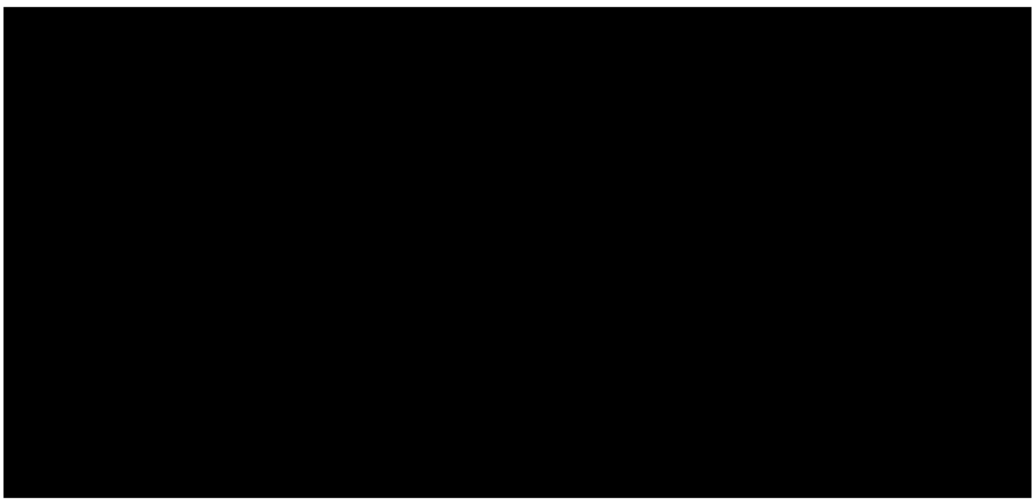

Figure-3
Lead accumulation in stems

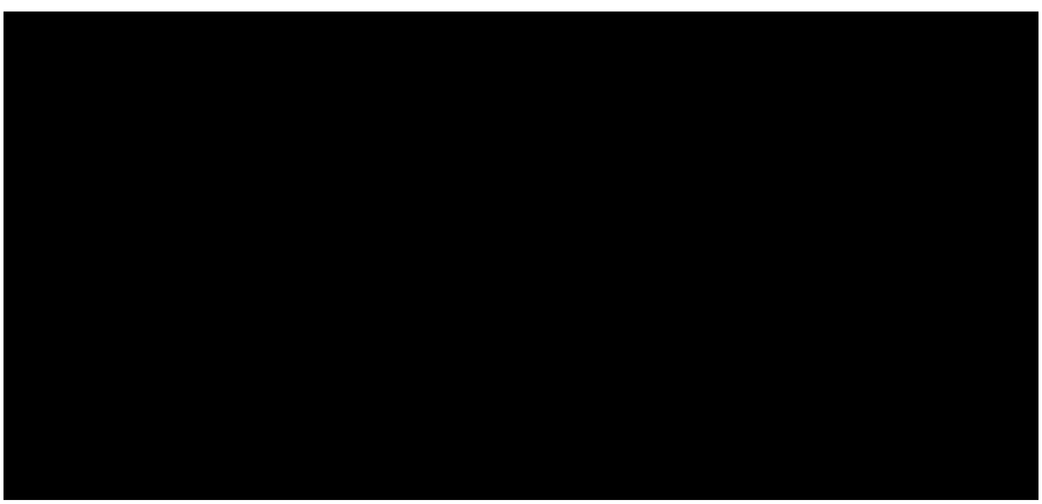

Figure-4
Lead accumulation in leaves

The comparison of lead uptake in plant and accumulation in different plant parts grown at different soil lead amendments can be visualized through figures 1, 2, 3 and 4. Lead content and accumulation in root, lead uptake by plant in Groundnut showed a linear relationship with soil Pb levels, while lead accumulation in stem and seed of Groundnut showed a curvilinear relationship.

Hapke[19] also reported linear relationships between Pb in soils and plants, however the extremely low slope caused a negligible increase of Pb concentration in plants even at a soil Pb in soil as high as 5400 µg/kg.

Xiong[18] reported that in seedlings (27 days) of *Sonchus Oleracecus,* the addition of Pb to the growth medium has significantly affected the concentration of Pb in leaf, stem, and root.

Rooney[1] *et al.* have worked on five species of vegetation grown on soils of lead shot shooting namely Barley, Lettuce, Rye grass, Radish and clover. All showed levels of lead in roots increased significantly with increase in soil Pb concentrations. Consistently higher concentrations of Pb were detected in the roots of all species in comparison with leaves except for rye glass at smaller concentration of soil Pb.

In the present studies the lead content of seed (edible part) is well above the maximum permissible limit for food stuffs, which is in agreement with Rooney *et al*[1] who reported that many of the plant concentrations were well above the maximum permissible limit for food stuffs (WHO/FAO maximum permissible limit of lead in food in 0.3mg/kg dry weight, Oyedele[20] *et al.* Root Pb levels were in agreement with Rooney[1] et al who reported that relationships between soil Pb and plant Pb concentrations were linear while curvilinear responses with increasing soil Pb were noted for the leaves. Edible plant concentrations in some cases exceeding the maximum permissible levels for human consumption were observed for lead in trace element content of vegetables grown in the greater industrial area of Thessoloniki[21]. Voutsa[10] *et al.* reported Pb levels of 0.49-15.5 µg/g, 0.05-0.1 µg/g, 0.31-16.5 µg/g 0.17-15.3 µg/g, 142-24.2 µg/g in cabbage, carrot, leek, lettuce and endive respectively in industrial area soils of Thesoloniki, N. Greece.

Zheljazkeov[22] *et al.* states that lead concentrations in plants generally depend on its soil concentrations. He further opines that most of the element is generally found in its root, which support the general understanding for the mechanism of uptake and translocation of this element with in plants. This is true in case of groundnut of the present study.

Leita [23] *et al.* reported very high soil Pb of 71000 µg/g and 4000 µg/g in vegetation grown at the mining area of south west Sardinia (Italy). They report that in spite of high heavy metal levels no signs of toxicity were apparent in vegetation. They reported high concentration of Pb in leaves, and low concentration were found in fruits in many plants, except in Fig trees where in the levels of total Pb was higher than in leaves, suggesting that some physiological barrier exists in plants which happens that translocation of Pb to the fruits.

Interest in the soil as a source of Pb for crop plants is heightened by the air borne Pb from automobile exhausts. The importance of air borne source is verified by the concentration of Pb in plants and soils along heavily traversed high ways. Brady[24] states that the behaviour of the element in soils would suggest that much of the Pb in food comes from atmospheric contamination.

Increase in Pb uptake in plant and accumulations in root with increase in substrate Pb level is also in agreement with John[25] who reported 2.3 - 71.3 µg/g in tops and 8 – 11208 µg/g in roots of lettuce exposed for six weeks to 0 – 50 µg/g of Pb in solution. Present results are in agreement with Mahtab Beladi[26] et al 2011, that with the increase in levels of lead in the soil, the absorption of lead in aerial parts increased; in Alfo alfa and Graas Pea. Present study is also in agreement with Abdul Ghani[27], 2010, who worked on maize varieties found their ability to accumulate Pb primarily in their roots and transport it to their leaves much lesser concentrations. Similar results were reported by Patra[9] etal 2004, Sinha[28] et al.

In research of Sudhakar[29] et al. the lead tolerance potential of six legume species, grown on lead ore tailings, the lead content of roots and leaves was significantly increased in all legume species grown on tailing.

Kumar[30] *et al.* also reported that supply of various concentrations of Pb^{+2} to intact sesamum seedlings increased Pb^{+2} concentrations in root, stem and leaves. In each tissue, the increase in internal Pb^{+2} concentration was well correlated with external Pb^{+} supply, although the magnitude of increase varied with plant part and concentration supplied.

The lead contents of roots, shoots and leaves of maize varieties increased significantly under the Pb stress when compared to control. The increase in Pb content of both varieties was found to be dependent on different Pb concentrations as observed by Abdul ghani[27]. Pb stored predominantly in roots and while shoots were less affected in both varieties. Similar results were reported by Bashmakov[31] et al. Yang[32] et al reported that when exposed to a solution containing Pb, the root biomass of the tolerant variety was higher than that of the sensitive rice variety because of the ability of the tolerant variety to develop adventitious roots.

Conclusion

Present study indicated that though the increased concentrations of soil Pb has no perceivable toxic impacts on the plant, significant loss in the productivity and the quality of the produce are unavoidable. Lead accumulation in the edible parts poses serious threats to the humans and the cattle through food chain concepts. Thus the quality of the produce of the agricultural crop cultivated in Pb contaminated soil will be so low and needs critical testing before its use.

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