© 2020 | International Journal of Scientific Research in Science and Technology
IJSRST | Volume 7 | Issue 2 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
DOI : https://doi.org/10.32628/IJSRST207275

Lead (Pb) Accumulation in Plants Grown on Contaminated Soil

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ABSTRACT

The effects of Pb treatments on Pb uptake by three food crops were investigated in a growth chamber experiment. Pb was added as Pb-acetate at the rates of 0, 200, 1000 and 2000 mg/kg soil. Lead concentrations in some plant parts were influenced more dramatically by soil Pb treatments than levels in other plant sections. Lettuce and carrot roots accumulated markedly higher Pb concentrations than the other plant parts. Since excessive dietary intake of Pb is undesirable, growth of Pb-responsive crops in contaminated soils should be avoided.

Keywords: Lead, Lettuce, Carrot, Growth Chamber, Dietary Intake

I. INTRODUCTION

Soil pollution with toxic metals such as lead (Pb) and their accumulation in soil is of great concern to food security and public health due to the adverse effects on crop productivity and human health [1]. Lead is a widespread contaminant in all areas of the world. It enters agricultural soils through atmospheric deposition and land application of municipal and industrial wastes. Concentrations ranging between 150-465 mg/kg have been measured from the forest floor of Europe and in mountainous regions of the north eastern United States [2,3]. Pb concentrations from 15-90 mg/kg [4,5] have been reported to occur in lower elevation forests of the eastern US, but have risen in the last 50 years due to increases in atmospheric deposition [6,7]. The phytotoxic effects of Pb are well documented [8,9;10,11]. The health hazard posed by excessive levels of Pb in soils is of great public concern. Therefore, accurate methods are needed to measure the plant availability of Pb where the soil abundance is increased several fold as a result of anthropogenic activities [12]. Pb concentrations in plants are dependent upon the degree of atmospheric lead pollution, seasonal and climatic effects [13,14,15] and the influence of soil pH and organic matter upon the availability of lead from the soil [16]. Experimental techniques employed in the present study were designed to eliminate variations in lead uptake which might be attributed to the above-mentioned factors. Those precautions and the separation of crops into various sections allowed the comparison of lead in several portions of three edible plants when they were subjected to four rates of soil Pb contamination.

II. METHODS AND MATERIAL

To maintain uniform conditions, a sample of silt loam soil, collected from Ecological Garden, Old Campus, Bayero University, Kano, Nigeria, was used in this study. The soil had 12.13% oxidisable organic matter and 39.2 Meq/100 g of cation exchange capacity. Pre-treatment with 5 g $CaCO_3$ per 1000 g of the 31.8%

base-saturated soil had increased its pH from 4.8 to 5.2. Uniform atmospheric and climatic conditions were provided by a growth chamber which regulated the temperature at 28 2 °C during a daily 14-hr photoperiod and at 20±2 °C during darkness. In the factorial experiment with three food crops times four rates of soil Pb treatment (0, 200, 1000, 2000 mg Pb/kg soil from Pb-acetate, $Pb(C_2H_2O_2)_2$) arranged in randomized blocks with three replications, plants were grown in 4-litre plastic pots each containing 2 kg oven dried soil. Macronutrient fertilization was done with the following: 0.91 g/kg of urea, 2.86 g/kg of 'super simple', 0.62 g/k of K-chloride and 0.33 g/kg of Mg-sulphate. The micronutrients were prepared in a 1L solution containing 11.54 g/ L of Cu-sulphate, 0.51 g/L of Na-molybdate, 25 g/L of Zn-sulphate and 2.94 g/L of boric acid. One ml of this stock solution per kg of soil was applied. Both liming and fertilization were performed with high-solubility analytical grade salts. The collection and planting of lettuce (*Lactuca sativa L., cv. Crispa, 'Salad Bowl'*), spinach (*Spinacia cleracea L., cv. 'King of Denmark'*) and carrots (*Daucus carota L. sativa, 'Chantenay Red Cored*) were done at International Institute of Tropical Agriculture (IITA) station, Tarauni Kano. Figures 1 and 2 show the maps of sampling and planting sites

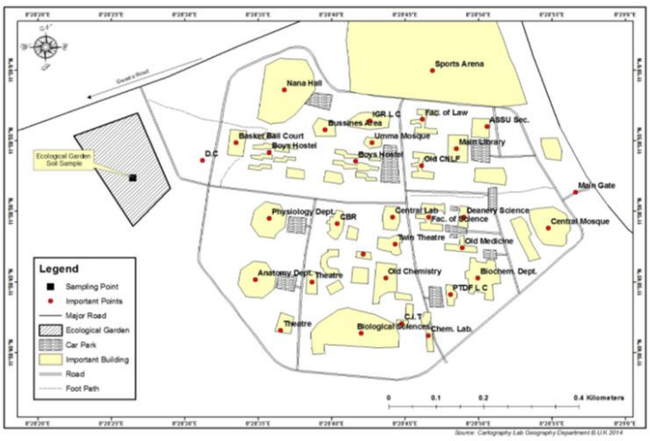

Fig.1: Map of Bayero University showing the Sampling Site

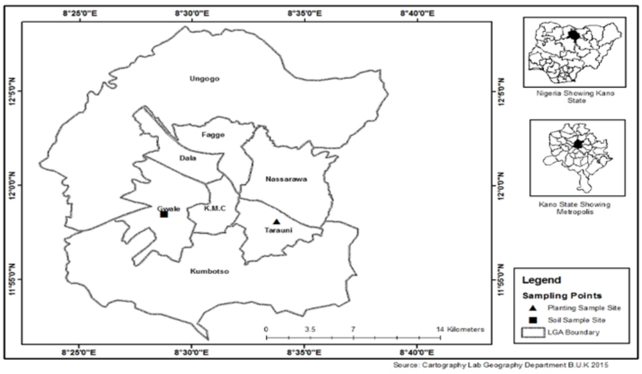

Fig.2: Map of Kano Metropolitan Showing Planting Site

At maturity, plants were harvested, separated into various parts, dried, ground, and digested with nitric-perchloric acid mixture. Lead concentrations were determined by atomic absorption spectrophotometry and expressed on a dry weight basis [18]. Collection, processing and statistical analysis of the data followed the computer methods described previously by SAS [17].

III.RESULTS AND DISCUSSION

Pb concentrations increased significantly in all of the plant parts as more Pb was added to the soil (F). Analyses of variance and Duncan's multiple range tests, performed for each of the seven plant portions, indicated that the effect of lead treatments was greater for some plant materials than others. Pb content in the leaves of lettuce and carrot tubers significantly (P = 0.05) increased by the addition of 200 mg Pb/kg soil. Whereas further significant enhancement of Pb levels in the leaves of lettuce and spinach resulted when the amount of Pb was increased from 1000 to 2000 mg Pb/kg soil, but for spinach leaves, accumulation which was only veryat 2000 mg Pb/kg soil, was significantly greater than corresponding level for the control plants.

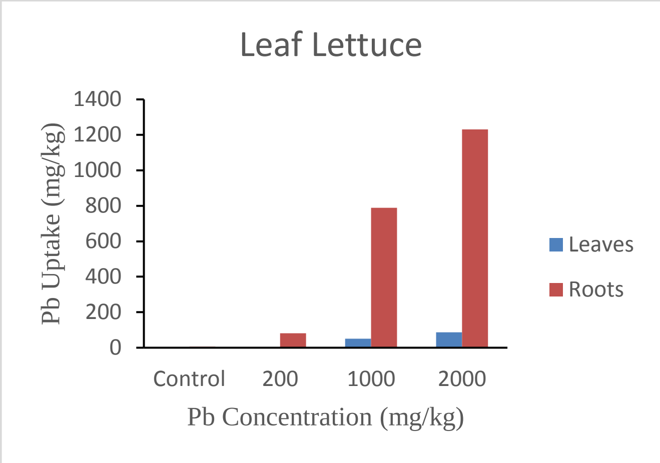

Fig.3: Pb Uptake in Lettuce plant

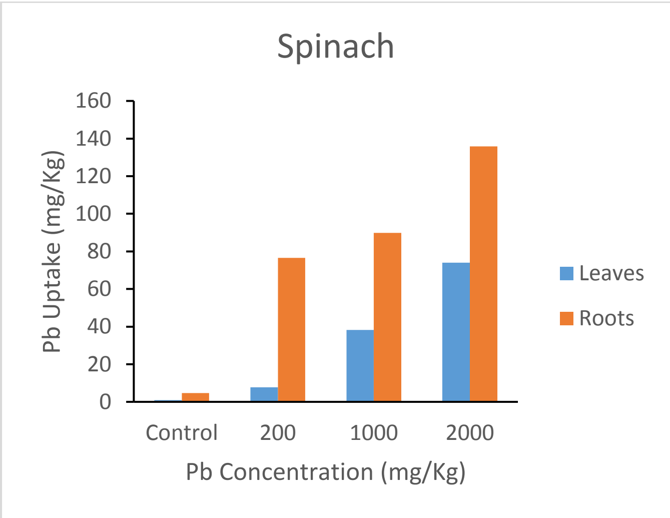

Fig.4: Pb Uptake in Spinach plant

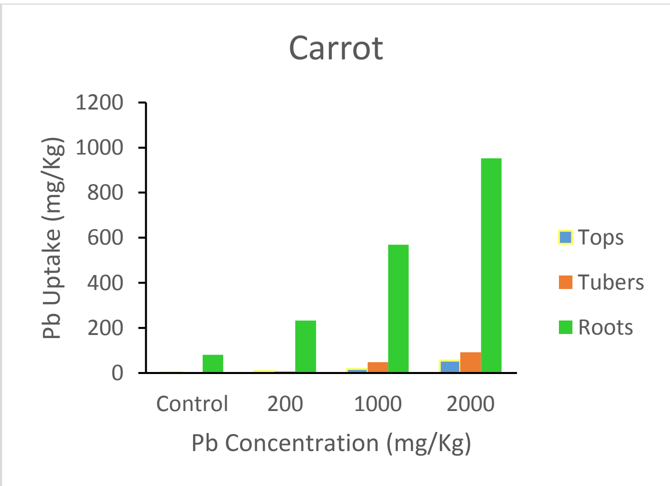

Fig.5: Pb Uptake in Carrot plant

Increases in lead content of carrot tubers were significant for all Pb treatments in the soil. There was a statistical significance between the Pb contents at 1000 mg/kg soil with the control and between the Pb levels at 200 and 2000 mg/kg soil. Distribution of Pb in different parts of plants grown in contaminated soils were reported by [19, 20, 18, 16]. Root portions absorbed and retained lead at greater concentrations than those found in the above-ground or tuberous tissues. Differences between lead concentrations in tissues of various plant species were studied for specific rates of soil lead. However, discussion here is limited to the high lead treatment for which these differences were most evident. Concentrations in root portions ranged from 135.766 to 1230.76 mg Pb/kg and increased with the following sequence of plant species: spinach, carrot and leaf lettuce. Among above-ground plant parts, lettuce and spinach leaves, with 87.783 and 73.942 mg of Pb/kg, respectively, contained higher lead levels than carrot tops. Intermediate Pb concentrations were determined in carrot tubers at 200 and 1000 mg Pb/kg soil and the least lead was held by carrot tops at same Pb treatments in soil. Tuberous portions of carrot plants accumulated Pb quantities similar to those in lettuce arid spinach leaves. When grown on the contaminated soil, these 3 tissues possessed markedly very high lead concentrations, the consumption of which would lead to greater dietary lead intake and an increased potential for health problems which have been associated with lead accumulation in man.

IV. CONCLUSION

Addition of lead acetate at the rates 0, 200, 1000 and 2000 mg/kg soil increased Pb uptake significantly in all parts of lettuce, spinach and carrots grown on the contaminated soils. There was a statistical significance between the Pb contents at 1000 mg/kg soil with the control and between the Pb levels at 200 and 2000 mg/kg soil. Root portions absorbed and retained lead at greater concentrations than those found in the above-ground or tuberous tissues. Among above-ground plant parts, lettuce and spinach leaves, contained higher lead levels than carrot tops. When grown on contaminated soils, tuberous portions of carrot, lettuce and spinach leaves contained markedly very high lead concentrations, which would cause potential health problems when consumed.

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Cite this article as :

Dagari M. S., Badamasi H., "Lead (Pb) Accumulation in Plants Grown on Contaminated Soil", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 7 Issue 2, pp. 401-405, March-April 2020. Available at doi : https://doi.org/10.32628/IJSRST207275
Journal URL : http://ijsrst.com/IJSRST207275