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Uptake of Lead by *Celosia Argentea* in an Ultisol

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Abstract: The experiment was carried out in the greenhouse at Faculty of Agriculture, University of Benin, Benin City to investigate lead uptake by *Celosia argentea* in an experiment organized in a completely randomized design with three replicates using four levels of lead at the rates of 0, 50, 100, 200mg/ 5kg soil. Results showed that the stem girth, number of leaves, height and dry matter of the plant decreased with increased Pb application with no significant differences among the various treatments. The decrease in Al_20_3, organic carbon, N, P, K, Mg, percentage base saturation, Ca and the increase in Fe_20_3, ECEC and exchangeable acidity were not consistent while the soil pH and Na content of soil were fairly stable. The Pb content of the soil increased with the increase in Pb treatment. The N, P, K, Mg and Ca content of the *Celosia argentea* and their uptake decreased with increased Pb application with the control significantly higher than other treatments. The Na content of the plant and the uptake were not consistent. The 200 mg Pb treatment was significantly higher in Pb content as well as its uptake by shoot and root. The amount of Pb in the root was however higher than that of the shoot at various levels of treatment.

Key words: Excluder, Lead, phyto-availability uptake, Ultisol.

INTRODUCTION

Technological advancement coupled with geometrical increase in world's population over the years have resulted in a build-up of large volumes of wastes in both urban and rural environments worldwide. Of all the major components of waste products and their derivatives, heavy metals are of great concern. The major hazards due to the disposal of these heavy metals via both natural and human activities is the contamination of soils. The increased uptake of heavy metal in polluted soils can cause accumulation in plant tissue and eventual phyto-toxicity and subsequent change in the plant community. Since heavy metal can accumulate in plant tissue, one of the ways in which its elevated concentration can enter human foods is through plant uptake and direct plant digestion by man and animal thereby causing health hazards to humanity. Oyinlola and Aliyu[17] also reported high uptake of Pb by tomato in soil treated with town waste. Begonia[4] found retarded growth and high Pb concentration in Indian mustard, Black mustard, radish, sunflower and morning glory plants while Kachenko and Singh[11] reported high concentration of Pb in lettuce, spinach, leek, and persley vegetables grown near metal smelter in Australia.

Generally, heavy metal phyto-availability varies with plant type, the duration of contamination and the soil characteristics[16]. Plant uptake of heavy metals according to Mole *et al*[14] may be higher in a soil with much lower total heavy metal concentration because the metal is phyto-available. Mole *et al*[14] reported further that a situation may occur where soils are enriched with heavy metals but plants are not contaminated due to low metal phyto-availability.

The test crop *Celosia argentea* L is of the family Amaranthaceae. It is a herbaceous annual plant whose upright stem vary between 0.5 m and 1.5 m in height. The leaves are distinctly longer on floriferous shoots. This plant is raised from seeds and is widely grown in many regions of tropical Africa especially Nigeria, Benin and Congo Kinshasha. It is highly consumed as leafy vegetables because of the high nutritive value. Therefore, the objective of this study was to determine the effect of Pb on some agronomic characters of *Celosia argentea* and some chemical properties of the soil.

MATERIALS AND METHODS

The pot experiment was conducted in the greenhouse at the Faculty of Agriculture, University of Benin, Benin City. The soil used was collected from 0-15cm depth of uncultivated field left fallow for 5 years. The soil sample was air-dried, sieved and the 5kg soil filled into the polythene pots. The pots were polluted with Pb $(NO_3)_2$ at rates of 0, 50, 100 and

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200mg and then left for two weeks to enable the Pb equilibrate with the soil. The experiment was laid out in a completely randomized design with 3 replicates. Each replicate had 20 pots with 5 pots per treatment.

The *Celosia argentea* seeds were sown in the nursery, left for 3 weeks before transplanting at one plant per pot. The seedlings were watered regularly with distilled water. Weeding was carried out regularly. The experiment lasted for 40 days when the plant height, number of leaves and stem girth were determined. Thereafter, the plants were harvested, separated into shoot and root parts and then oven dried at 78^0C for 48 hours to obtain a stable dry weight used in calculating nutrient uptake.

Soil pH was determined by using pH meter while the soil particle size was done by hydrometer method of Bouyoucos as modified by Day[6]. The organic carbon was determined by chromic acid wet oxidation procedure of Walkey and Black as modified by Black[5]. The total N was determined by micro-kjeldal procedure as described by Jackson[9] whereas the available P was extracted by using Bray No 1 P solution, and the P in the extract assayed calorimetrically by molybdenum blue colour method of Murphy and Riley[15]. The exchangeable bases were extracted using 1 N neutral ammonium acetate solution. The Ca and Mg content of the extract were determined volumetrically by EDTA titration procedure[5]. The K and Na were determined by flame photometry and Mg content obtained by difference. The exchangeable acidity was determined by methods of McLean[13] while the heavy metals and oxides were determined by methods Soon and Abboud[24]. The data generated were analyzed by Genstat statistical version 6.1.0 234[19].

RESULTS AND DISCUSSION

Properties of Soil Used: The soil properties are shown in Table 1. It is moderately acidic, classified as ultisol, dystric nitosol, Benin fasc and texturally sandy loam.

Chemical Properties of Soil Used after the Trial (Table 1): The soil pH decreased from 5.71 to 5.03 in control treatment and was however not consistent. The organic carbon, N and P also decreased from 21.10 gkg^{-1}, 1.30 gkg^{-1} and 2.19 $mgkg^{-1}$ to 10.50gkg^{-1}, 0.5gkg^{-1} and 1.20 $mgkg^{-1}$ in 100 mg Pb treatment respectively. The K, Mg, percentage base saturation and Ca, decreased from 0.12 $cmolkg^{-1}$, 0.12 $cmolkg^{-1}$, 34.04% and 0.76 $cmolkg^{-1}$ to 0.04 $cmolkg^{-1}$ in 200 mg Pb, 0.05 cmolkg-1 in 0 mg Pb and 200 mg Pb, 27.29% in 100 mg Pb and 0.66 $cmolkg^{-1}$ in 0 mg Pb respectively. The Na and Al_2O_3 also decreased from 0.12 $cmolkg^{-1}$ and 0.95% to 0.10 $cmolkg^{-1}$ in 50mg Pb and 0.07 cmolkg-1 in 0 mg Pb, 50mg Pb and 200 mg Pb treatments respectively. The decrease in these soil minerals such as N, P, K, Mg, Na, Ca and organic Carbon was however not consistent. This fluctuation may be due to plant uptake at different levels of Pb treatment. The decrease in Al_2O_3 may be due to its solubility because of low pH of the soil. Generally, oxide solubility is very low at the pH range of soils and depends on the particle size crystallanity and the percent Al substitution[23]. The exchangeable acidity, F_2O_3 oxide, Pb and ECEC content of the soil increased from 1.39 $cmolkg^{-1}$, 1.96%, 0.003 $mgkg^{-1}$ 3.29 $cmolkg^{-1}$ to 3.20 $cmolkg^{-1}$ in 100 mg Pb, 2.56% in 50 mg Pb, 82.99 $mgkg^{-1}$ in 200 mg Pb and 4.40 $cmolkg^{-1}$ in 100 mg Pb treatments respectively. The exchangeable acidity may have increased due to the reduction in the Mg and Ca content of the soil. The pH of soil may not have influenced the reduction in F_2O_3 hence the increase. However, the quantification of oxides in soils and sediments is often complicated by a considerable variation in crystallinity[22] but it is estimated that F_2O_3 concentration in various soils vary from <0.1 to > 50% and that may be evenly distributed in the matrix or concentrated in horizons concretion, mottles, bands or clay minerals coating as reported by Schwertmann[23]. The values of F_2O_3 obtained in this trial compared well with the estimated range reported by Schwertmann above. The increased Pb soil content is due to the amount applied to the soil. Tam and Singh[25] have earlier reported elevated heavy metals in heavy metal mine soils.

Some Minerals and Their Uptake (Tables 2 and 3): The shoot N, P, K, Mg and Ca content (Table 2) and their uptake (Table 3) decreased with increased Pb application. The control treatment however was significantly higher than other treatments. The Na content increased with increased Pb application with 200mg treatment significantly higher than other treatments while the uptake was not consistent but 50mg treatment significantly higher than other treatments.

The decrease in N, P, K, Mg and Ca content and uptake in the Pb treated plants may be due to the Pb physically blocking of mineral ions from absorption sites of roots as earlier reported by Rout and Das[21] with Norway spruce plants and with Brahmi plant[18]. Eun *et al*[7] also reported that high concentration of heavy metals in environment cause imbalance of minerals in growing plants. However, the observed action of Pb appear to be indirect as a result of mineral imbalance within the tissue of *Celosia argentea* bringing significant changes in nutrient in the plants under Pb toxicity. These actions could also be due to lack of oxygen[10], antagonism, and interference with the metabolism of mineral nutrients. The Pb may also

Table 1: Some chemical properties of the soil used

Treatment mg/5kg soil	Soil:H_2O(1:1)	Org C gkg^{-1}	N gkg^{-1}	Av P $mgkg^{-1}$	K	Mg	Ca	Na	Exch	ECEC	Base saturation	Fe_2O_3	Al_2O_3	Pb $mgkg^{-1}$
					------------cmolkg^{-1}----------			------------acidity-------------				--------(%)--------		
					Before	Pb	treatment							
	5.71	21.1	1.3	2.19	0.12	0.12	0.76	0.12	1.39	3.29	34.04	1.96	0.95	0.003
					After		harvest							
0	5.03	11.6	0.6	1.89	0.08	0.05	0.66	0.12	2.25	3.16	28.70	2.23	0.07	0.002
50	5.54	14.7	0.7	1.21	0.08	0.08	0.90	0.10	3.01	4.17	27.81	2.56	0.07	11.58
100	5.23	10.5	0.5	1.20	0.06	0.07	0.95	0.12	3.20	4.40	27.27	2.28	0.08	37.00
200	5.04	16.3	0.8	1.88	0.04	0.05	0.83	0.12	2.30	3.34	31.13	2.18	0.07	82.99

Table 2: Effect of Pb on some mineral content of *Celosia argentea* (%)

Treatment mg/5kg soil	N	P	K	Mg	Ca	Na
0	3.22a	0.29a	3.60a	1.54a	0.79a	4.94d
50	3.18b	0.27b	2.48b	1.63b	0.75b	5.29c
100	2.69c	0.23c	2.43c	1.58c	0.60c	6.11b
200	2.40d	0.20d	2.18d	1.56d	0.58d	6.34a

Values with the same letter are not significantly different from one another at $P \leq 0.05$

Table 3: Uptake of some minerals by *Celosia argentea* (gkg^{-1})

Treatment mg/5kg soil	N	P	K	Mg	Ca	Na
0	106.57a	9.52a	119.26a	54.31a	26.93a	163.50d
50	104.30b	8.84b	81.69b	53.65b	24.67b	174.60a
100	72.28c	6.21c	65.43c	42.39c	16.14c	164.40c
200	63.16d	5.33d	57.36d	41.15d	15.26d	166.81b

Values with the same letter are not significantly different from one another at $P \leq 0.05$

Table 4: The Pb content and its uptake by *Celosia argentea*

Treatment Mg/5kg soil	Shoot content (%)	Shoot uptake gkg^{-1}	Root content (%)	Root uptake gkg^{-1}
0	0.03d	0.35d	11.71d	136.40d
50	3.41c	111.74c	42.42c	484.80c
100	4.90b	131.29b	55.51b	528.10b
200	5.90a	154.34a	71.37a	567.90a

Values with the same letter are not significantly different from one another at $P \leq 0.05$

Table 5: Effect of Pb on some growth parameters and dry matter of *Celosia argentea*

Treatment mg/5kg soil	Plant height (cm)	Stem girth (cm)	No of leaves	Shoot dry weight (g)	Root dry weight (g)
0	42.10a	2.83a	28.33a	3.31a	1.20a
50	35.31a	2.37a	22.00a	3.29a	1.13a
100	32.90a	2.37a	21.33a	2.69a	0.96a
200	30.30a	2.33a	20.00a	2.63a	0.77a

Values with the same letter are not significantly different from one another at $P \leq 0.05$

have caused direct damage to the tissue cells of vascular bundles resulting in the inhibition of conduction of water molecules from root to aerial part of *Celosia argentea* hence reduction of the plant nutrients. The decrease in the nutrient uptake by shoot may be due to decrease in nutrient content because of increase Pb treatment.

The Pb Content and its Uptake by *Celosia argentea* (Table 4): The Pb content of the shoot and root and its uptake increased with increased Pb application. The 200 mg Pb treatment was however significantly higher than other treatments including control. Higher root Pb content as well as uptake was recorded when compared to that of shoot. The attribute of *Celosia argentea* accumulating more Pb in the root makes the plant to assume the positions of metal excluder. A metal excluder[20] plant prevents heavy metals from entering their aerial part or maintains low and constant metal concentration over a broad range of the concentration in soil and they mainly restrict metal in their root as shown by *Celosia*. The ability to restrict heavy metal to root is based on the mechanisms that actively growing roots provide a barrier that restricts the movement of heavy metals to above ground parts of the plant. This restricted movement by root in addition to low mobility of metals especially that of Pb may explain why metal concentration in shoots was relatively less than that of the root as earlier reported[11,12,4].

Effect of Pb on Plant Height, Stem Girth, Number of Leaves and Dry Matter (Table 5): The plant height, stem girth, number of leaves and dry matter yield decreased with increase in the Pb treatment. Although there were no significant differences among the treatments, the control treatments were higher than other treatments in all the parameters measured. The decrease in growth parameters may be due to the influence of the Pb especially at higher dosage. Stunted growth and dry matter yield in those treated with Pb is a commonly observed growth response in wide range of plants grown in metal-laden soils as reported earlier by Foy *et al.*[8]. The reduced shoot and root biomass of Pb treated plant can be due to specific toxicity of the Pb to the plant, antagonism with other nutrients in the plant. The concentrations of Pb in large amount have been reported to inhibit P_{700} of photosynthesis 1 and other enzymes activities. The inhibition of these enzymes would disturb the production of gluco-1-phosphate, which has an over-all effect on the formation of intermediates required for starting biosynthetic reaction[1], and then reduce growth in plants. The inhibition of root growth as demonstrated by the root weight after exposure to Pb may be due to decrease in Ca in root leading to decrease in Cell division or elongation. Similar results have been reported by Rout and Das [21] in Norway spruce plants and with Brahmi plants[18]. Azmat *et al*[3] have also reported that heavy metals significantly depressed leaf sizes and stem elongation in *Phaseolus mungo* and *Lens culinaris* crops.

Conclusion: The study revealed that the Pb had no influence on some mineral components of the soil and that Pb content of the soil increased with increased application. The growth parameters decreased with increase in Pb application. The Pb application also depressed nutrient content as well as their uptake in the plant. The *Celosia argentea* accumulates higher Pb in root than in the shoot and the accumulation increased with increased application. This gradual accumulation of this Pb in the shoot part of the plant and subsequent consumption could be hazardous to humanity.

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