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Phytoremediation Potential of Watermelon (*Citrullus lanatus*) Seedlings Planted on Lead Contaminated Soil in Katsina, Nigeria

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ABSTRACT: The objectives of this study is to investigate the phytoremediation potential of watermelon (*Citrullus lanatus*) seedlings planted on lead contaminated soil in Katsina, Nigeria using appropriate standard methods of physicochemical properties of the soil before and after the experiment and Atomic Absorption Spectrophotometer (AAS) measurements for Pb concentrations. The result revealed that the plant had accumulated a significant concentration of Lead in the leaves (18.112mg/kg), shoot (14.221mg/kg) and roots (9.100mg/kg) and there was no significant difference in the concentrations of Lead used in the study at $p>0.05$. The phytoextraction ability of *C. lanatus* was assessed in %remediation factor (RF), Bioconcentration factor (BCF) and elemental translocation factor (TF). The amount of Lead in the shoots and roots after 6weeks showed that more concentration of Lead was translocated from the roots to the leaves. The results of this investigation suggests that *Citrullus lanatus* could be used for phytoextraction of Lead from contaminated soil.

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Phytoremediation is the use of selected crop plants of trees to extract or promote degradation of toxic substances in soils, ground water, surface water, wastewater and sediments. It may be possible in some cases to harvest such contaminants as heavy metals that have been taken up by plants and recover them for recycling. In other variations, plants stimulate the growth of naturally occurring microbial populations, which then degrade organic contaminants, such as petroleum hydrocarbons, in soils. At appropriate sites, the cost of applying phytoremediation techniques may range from half to less than 20% of the cost of using physical, chemical, or thermal techniques. The Cucurbitaceae family belongs to the monotypic order Cucurbitales, class Magnoliopsida (subclass Rosidae), including about 435 species and varieties (Nee, 1990). The genus Cucurbita comprises 20 to 26 species (Cutler and Whitaker, 1961). All species of Cucurbita are genetically monotypic, containing 20 pairs of chromosomes ($2n = 40$). They are secondary polyploids with the base number $x = 10$. The shape, color and surface of the fruits of genus Cucurbita are extremely variable and often bizarre. Fruit sizes range from 4-15 cm (wild species) up to 1-2 m in diameter (Cucurbita maxima, which are the largest fruits known). The five cultivated species of the genus (*C. pepo L*, *C. maxima Duch*, *C. moschataDuch*, *C. argyrosperma Huber* and *C. ficifolia Bouche*) are reproductively inter-fertile. The terminology for the fruit is very diverse (like the fruit variability) (e.g. pumpkin, squash, gourd, etc.), and there are many slight differences in meanings. Uptake mechanisms of heavy metals and organic pollutants show molecular similarities in plant species. For example, spinach bioaccumulates POPs and heavy metals as well (Romer and Keller, 2002; Mattina *et al.,* 2002). This

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was also shown in the case of zucchini (Mattina *et al.*, 2003). These data suggest that plants showing high heavy metal uptake capacity are able to accumulate significant amount of organic pollutant as well. The present paper reports on Fast growing plants either monocots, dicots, trees or gymnosperms are capable of removing minerals, including heavy metals from polluted soils. This capability is powerful for phytoextraction and phytoremediation applied in situ (Bittsánszky *et al.*, 2009; 2011; Gyulai *et al.*, 2012a). For plant mineral uptake the plant ion and water channels are responsible. Water channel aquaporins (26–30 KD) are the main transmembrane proteins, which are responsible for the intensive water (and consequently the ion) uptake in the plants. The functional roles of aquaporins are quite similar to those of humans (Agre, 2003 in Knepper and Nielsen, 2004) and animals (Preston *et al.*, 1992). In higher plants, aquaporins consist of five subfamilies of the major intrinsic protein (MIP) superfamily.The objectives of this study as to investigate the phytoremediation potential of watermelon (*Citrullus lanatus*) seedlings planted on lead contaminated soil in Katsina, Nigeria.

MATERIALS METHODS

Study Area: This research was carried out in Federal College of Education Katsina. However the experiment was conducted in the College Biological Garden. Part of soil samples collected were artificially contaminated with Lead (Pb) in the form of Sulphate at a rate of 22mg/kg soil for Lead (Pb) while the other part of the soil was left as control.

Soil Particles Size Distribution: Particles distribution of the soil was performed using the pipette method that was described by Jackson (1970).

Soil pH: Soil pH was measured using a digital pH meter in a 1:1 suspension of soil-to-water ratio.

Soil Total Carbonate: Soil total carbonate was estimated gas metrically using a Collins Calcimeter and was calculated as CaCo3 (Nelson, 1982).

Soil Organic Matter Content: Organic matter content of the soil was determined using the dichromate oxidation method desPbibed by Wakley and Blackson (Mamdouh, *et al.*, 2011).

Soil Electrical Conductivity: The Electrical conductivity (EC) was estimated in 1:1 soil-to-water using digital EC meter of Hannna Model.

Lead (Pb) Extraction: Lead (Pb) was extracted from the study soil samples using a 0.005m DTPA (diethylenetriaminepenta acetic acid) solution buffered at pH 7.3 as desPbibed by Lindsay and Norvel (1969) in Mamdouh, (2011).

Determination of Total Heavy Metals: The method of Baker and Amacher (1982) desPbibed in Mamdouh, (2011) which involved digestion of samples in a mixture of HF-HNO3-HCLO4-H2SO4 in Teflon Beaker was employed to extract the total contents of Pb.

Screen House Experiment: A pot experiment in a Biological garden was conducted to study the ability of cucurbitaceae (*Citrullus lanatus)* to accumulate Pb. The seeds of study specie were soaked in water for three days with the renewal of water every day. Soaked seeds were placed in plastic pots (15cm in diameter and 20cm in depth) and filled with 5kg soil artificially polluted with Pb and irrigated as needed.

Plant Analysis: Plants were left in the pots for 6 weeks after germination. At the end of the experiment the plant samples was collected, washed twice with tap water and rinse with distilled water before separation into roots, shoots and leaves and oven dried (70^0C) to a constant weight. Dried roots, shoots and leaves were ground with pestle and mortar. The powder was digested with 2:1 of HNO_3:$HClO_4$ acid mixture. The digest was analysed for heavy metal (Pb) by Atomic Absorption Spectrophotometer (AAS) at Chemistry Laboratory of Umaru Musa Yar'adua University Katsina.

The metal uptake was calculated in order to assess the heavy metal phytoextraction efficiency and remediation factor (RF) was calculated as the percentage of the element removed by the plant dry above ground biomass from the total metal content in the soil (Neugshwandtner *et al*., 2008).

The translocation factor (TF) which will evaluate the capacity of a plant to transfer metals from root to shoot was also computed as the ratio of the metals concentration in the shoot with that in the root.

Statistical Analysis: Mean and errors in standard deviations were measured using MINITAB Version 8.0 Statistical Software.

RESULTS AND DISCUSSION

Table 1 shows the physicochemical properties of the soil before planting and after planting in which shows the physicochemical properties of soil after 6 weeks of phytoextraction studies. The high pH level of the soil is generally within the range of soil established by FEPA (1991). The pH of the soil after plant harvest

(7.08) was higher than the pH of the uncontaminated soil (6.2) probably, this may be due to the presence of Lead as a contaminant in the polluted soil.

Soil pH affects heavy metal sorption, as well as the solubility and hydrolysis of metal hydroxides, carbonates, and phosphates, as well as ion–pair formation and solubility of organic matter, as well as the surface charge of Fe, Mn, and Al-oxides, organic matter, and clay edges (Tokalioglu *et al*.,2006) These findings suggest that soil variables such as pH, clay, and organic matter influence metal uptake (Jung *et.al*., 1996).The unpolluted soil before planting had higher organic matter (8.48%) than the polluted soil which had5.07%. There was a slight decrease in nitrogen content while available phosphorous was higher in the polluted soil (18.00%) than the unpolluted (4.281%). The unpolluted soil before planting had 0.80, 0.05 and 0.03 cmol/kg of Na+, Mg2+ and Ca2+, respectively, while 3.02, 0.15 and 0.4 cmol/kg were observed for Na+, Mg2+ and Ca2+, respectively in the polluted soil after harvesting the plants.. Also, the effective cations exchange capacity (ECEC) was seen to be higher in polluted soils, (10.02 cmol/kg) than in unpolluted (2.02cmol/kg). The difference (increase or decrease in the soil properties) observed might be due to the Lead added in the soil. Lead (when added to soil) can change soil properties, according to Ryser and Sauder (2006), and data from studies on the toxic effect of heavy metals on soils have been used to establish the concentrations at which heavy metals affect biological soil processes for regulatory purposes, according to Giller *et al* (1998). Metal bioavailability insoil is a dynamic process that is influenced by a variety of chemical, biological, and environmental variables. Lead was not detected in minute quantities in unpolluted soil used for the experiment but 6 weeks after Lead pollution, Pb concentration was recorded and determined.

Table 1. Physicochemical Properties of the Soil before and after Planting

Parameters	Before Planting	After Planting
pH	6.2	7.08
Electrical Conductivity	0.072	0.147
Organic Carbon (%)	1.033	3.43
Organic Matter (%)	3.48	5.07
Total Nitrogen (mg/kg)	0.109	0.106
Water holding capacity	25.981	28.740
Sand (%)	66.8	51.20
Silt (%)	3.28	5.01
Clay (%)	29.92	31.07
Texture	Sandy loam	Loam
Available Phosphorus (mg/kg)	4.281	18.00
Calcium (cmol/kg)	0.03	0.4
Magnesium (cmol/kg)	0.05	0.15
Sodium (cmol/kg)	0.80	3.02
Exchange acidity (cmol/kg)	10.02	2.02
Effective cation Exchange capacity (cmol/kg)	8.03	10.31
Base saturation	63.3	78.04
Lead (mg/kg)	0.0003	7.567

The concentration of Lead recorded in the soil after 6 weeks of phytoextraction was less than the concentration of Lead introduced into the soil in their respective treatments. It was found that <0.0001, <0.0001, <0.0194, < 0.0001 and <0.0001mg/kg of residual Lead were detected in the soil treated with 10, 20, 30, 40, 50ppm of Lead, respectively. This indicated that large proportion of Lead was removed from the soil which could be traced to phytoextraction potential of the plant used. It could also be possible that some of the Lead might have escaped into the atmosphere. USEPA (2000) reported that heavy metals (when mopped up by plants) have the ability to escape into the atmosphere which could be in line with this finding. There was no significant difference in the different concentrations of Lead used in the study (p>0.05).In Lead contamination soils planted with *Citrullus lanatus*, the concentrations of Lead after 6weeks for leaves compartment were 2.203, 8.033, 12.932, 14.320 and 16.973 mg/kg, shoots were 1.914, 5.430, 8.510, 13.831 and 15.001 mg/kg and roots were 2.114, 5.871, 9.271, 14.117 and 14.406 mg/kg observed at 10,20,30,40 and 50ppm respectively. The results indicate that *Citrullus lanatus* mopped up substantial concentration of Lead in the above ground biomass compared to concentrations in the roots. The results also showed that, at the end of6 weeks period the leaves had the highest concentration of lead followed by the roots and shoots in that order.Huang and Cunningham (1996) and Blaylock *et al* (1997) found that plants can remove between 180 and530kg/ha of Pb and Pb/year, making remediation of sites contaminated with up to 2,500mg/kg possible in fewer than 10years. This implies that about 250mg/kg can be removed in a year at an average of 21mg/kg in4weeks. The value is far lower than Pb concentrations observed at the end of the sampling period (6weeks) in the *Citrullus lanatus.* This indicates that this plant is effective in mopping up the Pb from contaminated soil. Therefore, this plant has a potential to accumulate heavy metals and may be selectively used for phytoextraction of metal contaminated soils. According to emerging technology for the phytoremediation of metal in soil (ETPMS, 1997) phytoextraction is the ability of plants to absorb, concentrate, and precipitate toxic metals from contaminated soils, into the above ground biomass (shoots, leaves, stems and seeds).

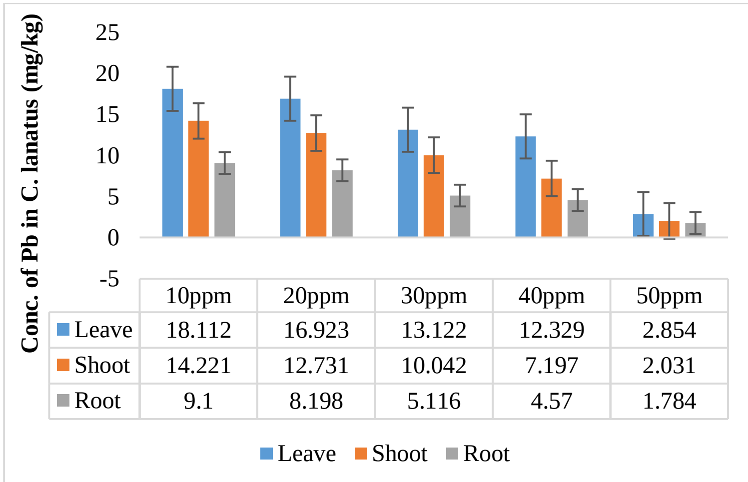

Fig 1. Concentrations of Lead in Leaves, Shoots and Roots of *Citrullus lanatus*

Table 2. Bioconcentration Factor (BCF), Remediation Factor (RF) and Translocation Factor (TF) of Lead in *Citrullus lanatus*

Treatment	**Bioconcentration Factor (BF)**	**Remediation Factor (R.F) (%)**		**Translocation Factor (T.F)**	
		Leaves	**Shoot**	**Leaves**	**Shoot**
00ppm(control)	0.00	0.00	0.00	0.00	0.00
10ppm	1.203	28.64	30.77	1.001	0.786
20ppm	1.083	26.76	27.54	1.045	0.786
30ppm	0.676	20.75	21.73	1.297	0.992
40ppm	0.604	19.34	15.57	1.302	0.759
50ppm	0.236	4.51	4.39	1.025	0.729

The highest BCF, RF, TR was recorded in soil polluted with 40 and 50ppm Pb. This might be due to the fact that at moderately low concentration of lead in the soil, plants tend to accumulate more metals than higher concentrations (Benzarti *et al.*, 2005). The highest TF in leaves and shoots was recorded in soil polluted with 10ppm. The ability of phytoremediation has commonly been characterized by a TF (Baker, 1981), which is defined as the ratio of the metal concentration in the shoots to that in the roots. Plants with TF values >1 are classified as high efficiency plants for metal translocation from roots to shoots. All the concentration of Pb in leaves showed TF_{values}>1 indicating that the plants could be classified as high efficient plant for metal translocation from the roots to the leaves. Wei and Chen (2008) suggested that plant species with TF values >1 actively take-up metals from the soil and accumulate them in their above ground parts; therefore they could be goodphytoremediators.

Conclusion: It is clear that phytoremediation has the potential to help restore equilibrium to a stressed ecosystem, but caution is advised. The ability of *Citrullus lanatus* to repair Pb-contaminated soil was established in thisstudy. This plant had the largest concentration of Pb in its leaves. However, planting *Citrullus lanatus* in a Pb-contaminated soil without a thorough investigation of the soil for Lead contamination could offer a significant risk to those who harvest the plant for consumption, as this plant has been reported to collect a significant amount of Pb.

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