
EFFECT OF SOIL LEAD CONTAMINATION ON THE GROWTH CHARACTERISTICS AND PHYTOREMEDIATION POTENTIAL OF SUNFLOWER (*HELIANTHUS ANNUUS* L.), COMMON DANDELION (*TARAXACUM OFFICINALE*) AND JATROPHA (*JATROPHA* *CURCAS* L.)

**Sumaila Muhammed Shaibu¹, Aliyu Adamu Dandajeh^{1,*}, Aliyu Ishaq¹, Alice Ibrahim
Onize², Raphael Owoicho Ejembi¹**

¹Ahmadu Bello University Zaria

²Bayero University Kano, Nigeria

Email: shaibusumailamuhammed@gmail.com, aadandaje@gmail.com*, aishaq@abu.edu.ng,
aliceibrahim15@gmail.com, raphaelejemb@gmail.com

***Corresponding author:** Aliyu Adamu Dandajeh

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ABSTRACT

Lead (Pb) contamination of soil is a persistent environmental problem because Pb is non-biodegradable, can remain in soil for long periods, and may adversely affect soil quality, vegetation, water resources and human health. This study evaluated the effects of Pb contamination on growth characteristics and the phytoremediation potential of sunflower (*Helianthus annuus* L.), common dandelion (*Taraxacum officinale*) and *Jatropha* (*Jatropha curcas* L.) under controlled pot conditions at the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria. Topsoil (0–20 cm) was collected, prepared and contaminated with Pb under controlled laboratory conditions. Three kilograms of prepared soil were placed in each pot, seedlings were established, soil moisture was maintained at approximately 65% field capacity, and plants were harvested after 60 days. Plant growth, residual soil Pb, Pb accumulation in roots, stems and leaves, and comparative phytoremediation indicators were assessed. Soil and plant samples were digested and analysed using atomic absorption spectrophotometry. Growth observations were summarized descriptively because seedlings within a pot are not independent experimental replicates. *Jatropha* recorded the lowest residual soil Pb concentration (82 mg/kg), the highest summed tissue Pb concentration (2,308 mg/kg), and the highest calculated soil Pb reduction (90.4%). Dandelion and sunflower showed calculated reductions of 65.6% and 64.5%, respectively. The highest translocation factors were observed for sunflower (1.84) and dandelion (1.82), compared with *Jatropha* (1.53). The findings indicate species-specific differences in Pb accumulation and partitioning under the tested conditions; however, the observed soil Pb reductions should be interpreted as preliminary because each species × treatment combination was represented by a single pot. Replicated greenhouse and field-scale studies are required to confirm treatment effects and remediation performance.

Keywords: lead contamination; phytoremediation; *Jatropha*; sunflower; dandelion; soil remediation; translocation factor

1.0 INTRODUCTION

Lead (Pb) contamination of soil is a persistent environmental concern because Pb is non-biodegradable and can remain in soil for long periods, with implications for soil quality, vegetation, water resources and human health. Phytoremediation uses plants and associated biological processes to reduce contaminant concentrations or toxicity and is regarded as a potentially lower-cost complementary approach for contaminated sites (Ali et al., 2013; Zhang et al., 2024).

Pb uptake and translocation are influenced by soil pH, particle size, organic matter, cation exchange processes, root characteristics and rhizosphere interactions. Plants may respond to Pb stress through root retention, cell-wall binding, sequestration and antioxidant defence (Rahman et al., 2024). These processes can produce substantial differences among plant species in Pb accumulation and partitioning.

Sunflower has demonstrated Pb uptake and translocation potential under controlled soil exposure (Ngabra et al., 2024). Recent evidence also indicates that common dandelion can accumulate trace elements, including Pb, across different plant tissues and can exhibit strong accumulation characteristics (Vural, 2024). Jatropha has likewise shown potential for phytoremediation of metal-impacted soils, including Pb, particularly where soil amendments improve plant growth and biomass production (Lim et al., 2024).

Despite these advances, comparative evidence for sunflower, common dandelion and Jatropha evaluated under comparable controlled Pb exposure remains limited. Comparative screening is useful because remediation performance should be considered alongside plant growth, tissue accumulation and Pb partitioning. The present study therefore evaluates the three species under controlled pot conditions, with emphasis on observed soil Pb reduction, tissue accumulation, translocation and selected growth characteristics.

The aim of this study was to investigate the effects of soil Pb contamination on the growth characteristics and comparative phytoremediation potential of sunflower, common dandelion and Jatropha under controlled pot conditions. The specific objectives were to: (i) determine the observed growth responses of the three species under Pb exposure; and (ii) determine and compare observed soil Pb reduction, tissue accumulation and translocation characteristics.

2.0 MATERIALS AND METHODS

2.1 Experimental Design and Study Area

The study employed a controlled environmental pot experiment to compare the growth response and Pb-remediation indicators of sunflower (*Helianthus annuus* L.), common dandelion (*Taraxacum officinale*) and Jatropha (*Jatropha curcas* L.). The experiment was conducted at the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, Kaduna State, Nigeria (approximately 11°11'N, 7°38'E; 686 m above sea level). Six plastic pots were used: one Pb-treated pot and one uncontaminated control pot for each species. Each pot contained 3.0 kg of soil. Three seedlings of each species were monitored within the corresponding pot for growth measurements. Because the three seedlings within a pot shared the same soil environment, they were treated as within-pot observations rather than independent pot-level replicates.

The experimental arrangement permits preliminary descriptive comparison of growth measurements but does not provide independent replication for treatment-level inference. Accordingly, soil Pb reduction, tissue Pb accumulation, the whole-plant Pb accumulation index and translocation factor were reported descriptively.

2.2 Experimental Materials

The experimental materials comprised topsoil, plastic pots, sunflower seeds/seedlings, dandelion and Jatropha seedlings, lead nitrate [Pb(NO₃)₂], deionized and distilled water, urea fertilizer, sieves and laboratory glassware. Major equipment included an electronic balance, oven, mortar and pestle, microwave digestion system, wet digester, pH meter, flame photometer, UV–Visible spectrophotometer and Zeenit 700P atomic absorption spectrophotometer (AAS).

2.3 Soil Preparation and Lead Contamination

Topsoil was collected from the 0–20 cm depth within the study area. Plant residues, stones and other debris were removed, after which the soil was air-dried, gently disaggregated and passed through a 2.0-mm nylon sieve. Soil description and classification procedures were consistent with standard soil-survey practice (U.S. Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS], 2017). Selected soil properties included pH (7.57), organic matter (2.72%), total organic carbon (1.58%), available phosphorus (4.68 mg/kg), potassium (138 mg/kg), bulk density (1.25 g/cm³) and sandy-loam texture.

Pb-treated soil was produced in the laboratory using the predetermined Pb-loading protocol and appropriate laboratory safety procedures. The measured initial Pb concentrations were 572 mg/kg for sunflower, 800 mg/kg for dandelion and 851 mg/kg for Jatropha. These measured values were used as the experimental starting concentrations for calculating percentage soil Pb reduction because

they represent the analytical baseline. Differences among starting concentrations indicate that the species-associated pots did not begin at identical measured Pb concentrations; consequently, cross-species comparisons of percentage reduction are preliminary rather than fully controlled treatment comparisons.

2.4 Plant Establishment and Experimental Management

Healthy and relatively uniform seedlings of sunflower, dandelion and *Jatropha* were established in their respective contaminated and control pots following soil equilibration. All pots were maintained under similar environmental conditions, with soil moisture maintained at approximately 65% of field capacity through regular watering. Where fertilizer was applied, the same quantity and procedure were used across treatments.

Plants were monitored throughout the experiment, and growth characteristics were recorded periodically. Plants were harvested after 60 days. At harvest, plant height, root length and fresh and dry biomass were determined. Plant tissues were separated into roots and shoots, with shoots further divided into stems and leaves where required.

2.5 Sample Preparation and Lead Analysis

Plant tissues were washed with tap water and deionized water, oven-dried to constant weight, ground using an agate mortar and pestle, and passed through a 0.25-mm nylon sieve. Post-experiment soil samples were air-dried and passed through a 2.0-mm sieve. Approximately 0.5 g of soil and 0.1000 g of dried plant material were subjected to acid digestion using the laboratory-established procedure, with the resulting digests diluted to known volumes with deionized water. The general analytical approach is consistent with established methods for heavy-metal determination in soils (Davidson, 2012). Lead concentrations were determined using a Zeenit 700P atomic absorption spectrophotometer after calibration with Pb standards. Reagent blanks and duplicate samples were included as quality-control measures.

Determination of Element Concentration

Element concentration was calculated using the following mass-balance conversion:

$$C_{\text{element}} \text{ (mg/kg)} = [(C_s - C_b) \times V \times DF] / W \quad (1)$$

where C_{element} is the concentration of the element in the sample (mg/kg); C_s is the sample concentration obtained from the instrument (mg/L); C_b is the blank concentration (mg/L); V is the final extraction or digestion volume (mL); DF is the dilution factor; and W is the mass of sample analysed (g).

2.6 Evaluation of Phytoremediation Potential and Data Analysis

The comparative phytoremediation assessment used observed soil Pb reduction, Pb concentrations in roots, stems and leaves, a study-specific whole-plant Pb accumulation index, translocation factor (TF), and selected plant-growth observations. Microsoft Excel 2016 was used for data organization and calculations, while IBM SPSS Statistics Version 22 was used to organize the growth observations. Because there was only one pot per species $\times$ treatment combination, inferential tests based on seedlings within the same pot were not treated as independent treatment-level evidence. The growth results are therefore presented descriptively.

Observed soil Pb reduction was calculated as:

$$\text{Soil Pb reduction (\%)} = [(C_i - C_f) / C_i] \times 100 \quad (2)$$

where C_i is the measured initial soil Pb concentration (mg/kg) and C_f is the final soil Pb concentration (mg/kg). This metric represents calculated concentration reduction and should not be interpreted as proof of plant-mediated Pb removal because leaching, redistribution and other mass-balance processes were not independently quantified.

Total Pb remaining in soil (mg) = final soil Pb concentration (mg/kg) $\times$ soil mass (kg).

A study-specific whole-plant Pb accumulation index was calculated as:

$$\text{Whole-plant Pb accumulation index} = (\text{Root Pb} + \text{Stem Pb} + \text{Leaf Pb}) / \text{Initial soil Pb}$$

(3)

The index is a comparative ratio developed for this dataset and should not be labelled as a conventional bioaccumulation factor (BCF) because the numerator is a summed tissue concentration rather than a biomass-normalized plant concentration.

Translocation factor (TF) was calculated as:

$$TF = (\text{Stem Pb} + \text{Leaf Pb}) / \text{Root Pb}$$

(4)

A TF greater than 1 indicates that the combined stem and leaf Pb concentration exceeded the root Pb concentration under the calculation used. Data were compared descriptively among species and treatments.

3.0 RESULTS AND DISCUSSION

3.1 Soil Properties and Lead Loading

The experimental soil had a pH of 7.57, indicating a slightly alkaline reaction. Organic matter (2.72%) and total organic carbon (1.58%) were moderate, while available phosphorus (4.68 mg/kg) was low. Exchangeable potassium was 138 mg/kg, calcium 7.40 mg/kg, sodium 184 mg/kg and magnesium 2.00 mg/kg. Bulk density was 1.25 g/cm³ and total porosity was 52.8%. The particle-size distribution of 62% sand, 28% silt and 10% clay classified the soil as sandy loam. Soil pH, texture and organic matter can influence Pb retention, mobility and plant availability (Rahman et al., 2024; Zhang et al., 2024).

Table 1: Baseline physicochemical properties of the experimental soil.

Parameter	Value	Unit	Interpretation
Soil pH	7.57	—	Slightly alkaline
Organic matter	2.72	%	Moderate
Total organic carbon	1.58	%	Moderate
Available phosphorus	4.68	mg/kg	Low
Exchangeable K	138	mg/kg	Moderate
Exchangeable Ca	7.40	mg/kg	Very low
Exchangeable Na	184	mg/kg	High
Exchangeable Mg	2.00	mg/kg	Low
Bulk density	1.25	g/cm ³	Good
Total porosity	52.8	%	High
Textural class	Sandy loam	62% sand; 28% silt; 10% clay	Sandy loam

Source: Researcher fieldwork (2026); soil-description framework informed by USDA-NRCS (2017). Available phosphorus determination was based on the reported laboratory procedure and the Olsen method (Olsen et al., 1954).

3.2 Residual Soil Pb and Plant Uptake

Measured baseline concentrations differed among the species-associated pots, with initial soil Pb of 572 mg/kg for sunflower, 800 mg/kg for dandelion and 851 mg/kg for Jatropha. After 60 days, final soil Pb concentrations were 203, 275 and 82 mg/kg, respectively. Jatropha also had the highest summed tissue Pb concentration (root + stem + leaf = 2,308 mg/kg), followed by dandelion (1,576 mg/kg) and sunflower (1,108 mg/kg). These results indicate strong species-specific differences in tissue Pb accumulation under the tested conditions, but the lack of independent pot replication prevents a statistical claim that species caused the observed differences.

Table 2: Initial and final soil Pb concentrations and Pb accumulation in plant tissues.

Species	Initial soil Pb (mg/kg)	Final soil Pb (mg/kg)	Root Pb (mg/kg)	Stem Pb (mg/kg)	Leaf Pb (mg/kg)	Summed tissue Pb (mg/kg)
Sunflower	572	203	390	388	330	1,108
Dandelion	800	275	558	465	553	1,576
Jatropha	851	82	913	800	595	2,308

3.3 Calculated Soil Pb Reduction

Using the measured initial and final concentrations, the calculated soil Pb reductions were 64.5% for sunflower, 65.6% for dandelion and 90.4% for Jatropha. Jatropha therefore had the largest observed concentration reduction. However, because initial concentrations differed and only one pot represented each species $\times$ treatment combination, the ranking should be interpreted as a preliminary screening result rather than definitive evidence of superior phytoremediation efficiency.

Table 3: Calculated soil Pb reduction after 60 days.

Species	Initial Pb (mg/kg)	Final Pb (mg/kg)	Calculated reduction (%)	Descriptive rank
Jatropha	851	82	90.4	1
Dandelion	800	275	65.6	2
Sunflower	572	203	64.5	3

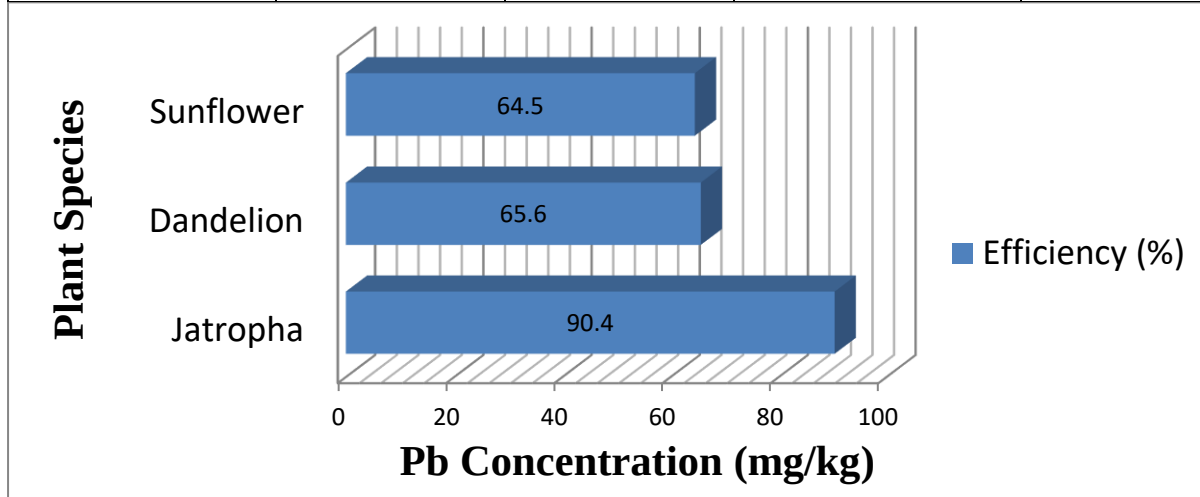


Figure 1: Calculated percentage reduction in soil Pb concentration after 60 days.

3.4 Whole-Plant Pb Accumulation Index

The whole-plant Pb accumulation index was 1.94 for sunflower, 1.97 for dandelion and 2.71 for Jatropha. Jatropha therefore recorded the highest comparative tissue-to-initial-soil ratio. The result is consistent with the high tissue Pb concentrations observed in Jatropha and with recent evidence that Jatropha can accumulate Pb and other metals under contaminated-soil conditions (Lim et al., 2024).

Table 4: Study-specific whole-plant Pb accumulation index.

Species	Root Pb	Stem Pb	Leaf Pb	Summed tissue Pb	Initial soil Pb	Accumulation index
Sunflower	390	388	330	1,108	572	1.94
Dandelion	558	465	553	1,576	800	1.97
Jatropha	913	800	595	2,308	851	2.71

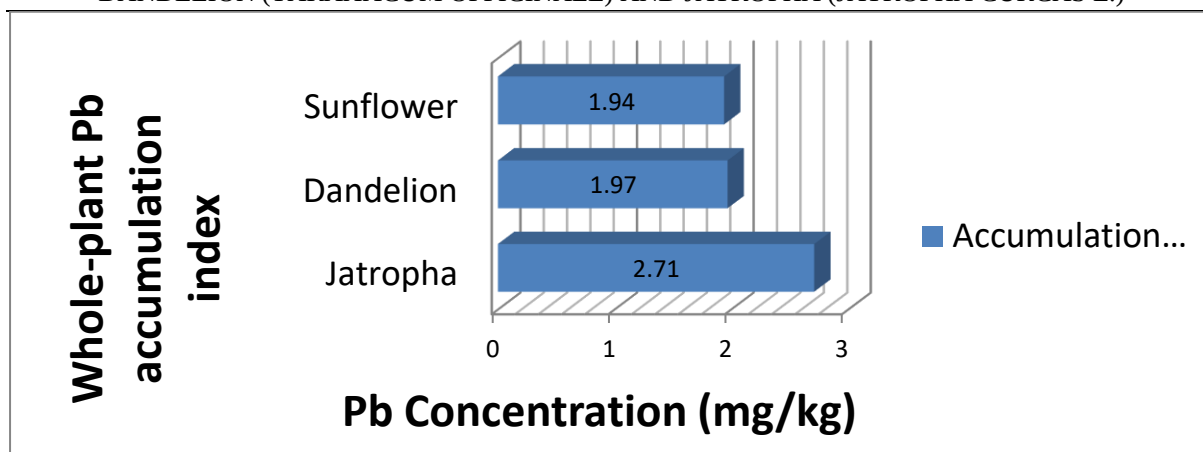


Figure 2: Whole-plant Pb accumulation index.

3.5 Translocation Factor of Lead

Sunflower and dandelion recorded higher TF values (1.84 and 1.82, respectively) than Jatropha (1.53). This indicates relatively greater partitioning of the measured Pb concentration into stem and leaf tissues for sunflower and dandelion under the calculation used. The finding is broadly consistent with evidence that plant species differ in Pb partitioning among roots and above-ground tissues (Rahman et al., 2024; Vural, 2024).

Table 5: Translocation factor (TF) of Pb.

Species	Root Pb (mg/kg)	Stem Pb (mg/kg)	Leaf Pb (mg/kg)	TF = (Stem + Leaf)/Root
Sunflower	390	388	330	1.84
Dandelion	558	465	553	1.82
Jatropha	913	800	595	1.53

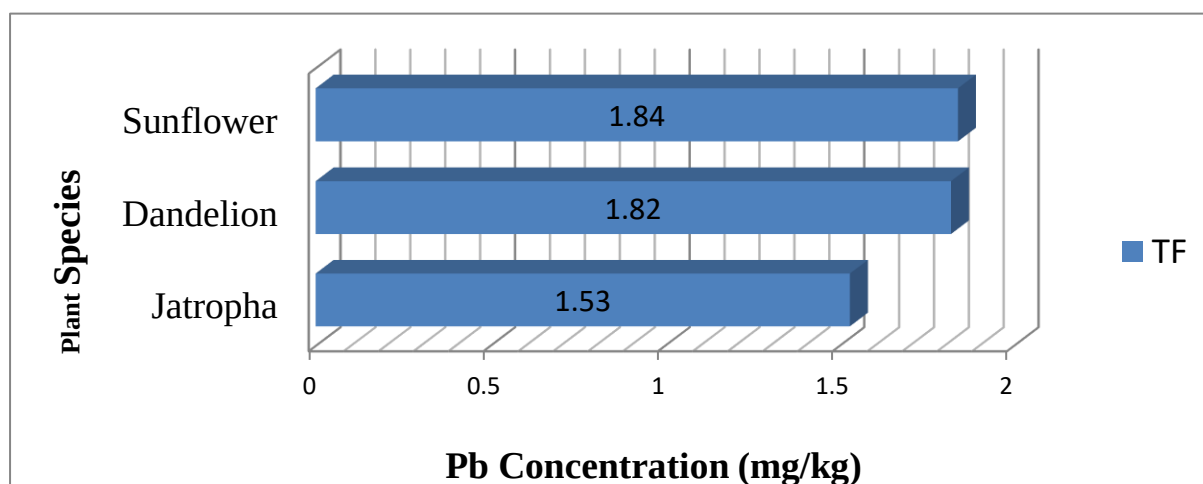


Figure 3: Translocation factor of Pb.

3.6 Growth Characteristics under Pb Stress

The recorded height observations were similar across species, with values generally ranging from 23 to 27 cm. Sunflower recorded 24–25 cm under the contaminated treatment and 23–25 cm under the control treatment; dandelion recorded 24–24 cm and 24–25 cm, respectively; while Jatropha recorded 25–25 cm and 25–27 cm, respectively. Leaf counts showed a wider numerical range, with Jatropha recording fewer leaves under the contaminated treatment than sunflower and dandelion. Because only one pot was used for each species × treatment combination, the apparent differences among seedlings cannot be treated as independent replicated treatment effects. The growth data are therefore presented as descriptive observations rather than inferential statistical evidence.

Table 6: Descriptive growth observations recorded during the experiment.

Species	Contaminated height M1 (cm)	Contaminated height M2 (cm)	Control height M1 (cm)	Control height M2 (cm)	Contaminated leaves M1	Contaminated leaves M2	Control leaves M1	Control leaves M2
Sunflower	24	25	23	25	22	20	22	23
Dandelion	24	24	24	25	20	18	21	22
Jatropha	25	25	25	27	17	15	18	20

M1 = first measurement occasion; M2 = second measurement occasion.

3.7 Interpretation and Comparison with Related Studies

Jatropha showed the strongest observed soil Pb concentration reduction, while sunflower and dandelion showed higher TF values. Several mechanisms may contribute to species differences, including root characteristics, soil pH, organic matter, rhizosphere interactions, cell-wall binding and physiological tolerance (Rahman et al., 2024; Zhang et al., 2024). These mechanisms were not directly measured in the present experiment and therefore should be regarded as plausible explanations rather than demonstrated causal mechanisms.

The strong tissue accumulation observed in Jatropha is compatible with recent work showing that *J. curcas* can accumulate Pb and other metals in contaminated substrates and that improved soil conditions can increase plant biomass and metal removal (Lim et al., 2024). Sunflower has also been reported to accumulate Pb under controlled soil-spiking conditions (Ngabra et al., 2024), while Vural (2024) documented substantial trace-element accumulation by *T. officinale*, including Pb, across plant tissues. The present results therefore support the value of these species as candidates for further comparative screening, but they do not establish field-scale remediation efficiency.

The calculated reductions of 64.5%, 65.6% and 90.4% are arithmetically consistent with the measured initial and final soil concentrations. Nevertheless, a reduction in measured soil concentration is not equivalent to a verified mass of Pb removed from the experimental system. Future studies should include replicated pots, randomized treatment allocation, identical measured starting concentrations, complete soil and plant Pb mass balances, and measurements of Pb bioavailability and soil Pb fractions.

4.0 CONCLUSION

Under the controlled conditions tested, Jatropha recorded the lowest final soil Pb concentration (82 mg/kg), the highest calculated soil Pb reduction (90.4%) and the highest study-specific whole-plant Pb accumulation index (2.71). Sunflower and dandelion recorded higher translocation factors (1.84 and 1.82) than Jatropha (1.53), indicating greater relative partitioning of measured Pb into above-ground tissues. Growth observations showed numerical differences among species, but the experimental design did not provide independent pot-level replication for inferential testing. Overall, the findings identify Jatropha as the strongest preliminary candidate for further Pb-phytoremediation evaluation under the tested conditions, while emphasizing that replicated greenhouse and field studies are required before definitive species-performance claims are made.

4.1 RECOMMENDATIONS

1. Jatropha should be prioritized for replicated greenhouse and field-scale trials where the objective is soil Pb reduction and plant accumulation, while treating the present ranking as preliminary.
2. Sunflower and dandelion should be investigated as complementary species where above-ground Pb translocation and biomass harvesting are important remediation considerations.
3. Future experiments should use independent replicated pots, randomized treatment allocation, identical measured starting Pb concentrations, longer exposure periods, direct measurements of Pb bioavailability and soil Pb fractions, and complete plant–soil Pb mass balances.
4. Pb-contaminated plant material should be handled, transported and disposed of in accordance with applicable institutional hazardous-material procedures, and future field studies should assess soil

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heterogeneity, moisture variation, microbial interactions, mixed-metal contamination and seasonal effects.

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