Journal of Tropical Forest Science 36(4): 402–415 (2024)
https://doi.org/10.26525/jtfs2024.36.4.402
ISSN: 0128-1283, eISSN: 2521-9847

APPLICATION OF *DENDROCALAMUS ASPER* (SCHULT.) BACKER (BULUH BETONG) WITH THE COMBINATION OF BAMBOO BIOCHAR AND EDTA IN PHYTOREMEDIATION

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Submitted January 2024; accepted June 2024

Phytoremediation technology utilises the ability of plants to remove metal toxicity in the soil. Bamboo is one of the fast-growing woody plants that may potentially facilitate the immediate removal of toxic metals from the soil. This study was conducted to identify the potential of *Dendrocalamus asper* in phytofiltering metal elements from the mining sites such as the Chini watershed in Pahang. *Dendrocalamus asper* was grown in a greenhouse with several applications of bamboo biochar (BB) and EDTA in addition to the efficiency test in reducing soil contaminants for 100 days. The present study found *Dendrocalamus asper* with the addition of BB+EDTA had reduced 37.44% Fe, 43.72% As, 79.27% Pb, 22.67% Cd, and 48.60% Al concentration in the soil. The same treatment also showed a higher plant accumulation of metal concentrations Pb (31-fold) followed by Al (1.3-fold), Cr (1.3-fold), As (1.05-fold), Fe (82%) and Cd (81%) compared to the control. Growing bamboo with the combination of BB+EDTA was found to be useful for Pb phytoextraction and suitable as a phytostabiliser for Al, Fe, As, Cr and Cd. The understanding in the potential of *Dendrocalamus asper* in reducing soil contaminants may benefit stakeholders in managing and restoring contaminated sites in the future.

Keywords: *Dendrocalamus asper*, Buluh Betong, phytoremediation, mining site, Tasik Chini, Peninsular Malaysia

INTRODUCTION

Soil plays a critical role in supporting ecosystems and living organisms since it is a medium for plant growth (Cassidy et al. 2013, Hou et al. 2020, Jansson & Hofmockel 2020)industrial and agricultural activity is often detrimental to soil health and can distribute heavy metal(loid. Soil contains a wide range of elements due to the natural weathering process, some of them are important elements in trace amounts in agricultural soil. However, widespread soil contamination and degradation are caused by anthropogenic activities (Foley et al. 2011, Borrelli et al. 2017, Hou et al. 2020)industrial and agricultural activity is often detrimental to soil health and can distribute heavy metal(loid. The bioavailability of toxic metals in soil can be significantly impacted by various activities, including mining, smelting, atmospheric deposition, irrigation with contaminated water, and the use of metal-containing fertilisers or agrochemicals in agricultural practices thus impacting their accumulation in food crops and food security (Zhao et al. 2022)leading to excessive accumulation of arsenic (As. One of the negative impacts of mining activities can be seen in the Chini watershed, Pahang.

Chini watershed in Pahang is one of the largest freshwater lakes in Malaysia, which is recognised as the first UNESCO Man and Biosphere Reserve site to be conserved for its natural, biological, and cultural resources (Sharip et al. 2018, Rendana et al. 2023).

Anthropogenic activities surrounding the area included mining, rubber plantations, oil palm plantations, forests, and tourism. Factors such as location, changes in land use, barite and iron mining sites, and the area surrounding the Chini watershed catchment area were the main causes of increased soil pollution. Furthermore, in the watershed area, deforestation has increased the rates of soil erosion (Rendana et al. 2023). Therefore, phytoremediation technology can be implemented in soil restoration.

Numerous studies have been conducted recently on the use of the phytoremediation approach for metal-contaminated soil. Phytoremediation is a green technology that utilises plants to remove contaminants from soil, sediments, and water with minimal impact on the environment. Phytoextraction, phytodegradation, phytostabilisation, phytovolatilisation, and rhizofiltration are the several types of phytoremediation process (Rajoo et al. 2016). The criteria used for phytoremediation selected plants must possess high biomass and high metal uptake, and generally, most metal hyperaccumulators were found to have the potential for phytoremediation (Salem et al. 2018).

It was estimated around 500 angiosperms species worldwide were considered metal hyperaccumulators (Kr mer 2010) and among them are within the families of Poaceae, Cyperaceae, Brassicaceae, Asteraceae, Caryophyllaceae, Fabaceae, Lamiaceae, Euphorbiaceae, Violaceae, and Cunoniaceae (Prasad & Freitas 2003, Mahmud & Bruslem 2018). According to several researchers, bamboo species (Poaceae) were also suitable candidates for heavy metal phytoremediation (Chen et al. 2014, Yan et al. 2015, Bian et al. 2020). Even though bamboo does not qualify as a metal hyperaccumulator, it still meets the requirements for phytoremediation as several bamboo species can survive in metalliferous environments and grows fast to meet the needs for high biomass production. This characteristic might assist in immediately removing toxic metals from water or soil (Bian et al. 2020). In Malaysia, it was reported that 14 bamboo species out of 50 native bamboo species are known to be commercially utilised (Wong 1989). Globally, bamboo is used widely in various industries such as agriculture, pulp & paper, and building. Additionally, the byproducts of bamboo, like biochar, may play a role in reducing soil metal contaminants and improving soil fertility (Wang et al. 2019).

Research on the environmental effect on enhancing metal phytoextraction was previously reported by several researchers (Evangelou et al. 2007, Farid et al. 2013). Internal and external environmental factors, including soil qualities, metal availability, and chelator regulation, may restrict the effective use of phytoremediation (Hernández-Allica et al. 2007, Hamidpour et al. 2010, Shahid et al. 2014, Jiang et al. 2019). Thus, several soil conditioners might be useful in enhancing the efficiency of phytoremediation. One of the soil conditioners made by thermochemically breaking down organic compounds in anaerobic environments is biochar. The utilisation of biochar presents a promising solution to mitigate the bioavailability and leachability of heavy metals due to its substantial surface area and exceptional adsorption capability of organic contaminants and heavy metals (Zhang et al. 2013). There have been numerous reports on the application of biochar to soil has improved plant development and greatly enhanced crop harvests (Steiner et al. 2007, Major et al. 2010, Zhang et al. 2017). Moreover, biochar increases the adsorption of dissolved organic carbon (Li et al. 2018b), increases soil pH and soil nutrients, and reduces the trace metals in leachates (Novak et al. 2009, Li et al. 2018a).

Besides biochar, organic chelating agents such as ethylenediaminetetraacetic acid (EDTA) chelate different heavy metals in the soil. EDTA has been applied to plants to enhance the bioavailability of metals, particularly those with low soil bioavailability of heavy metals (Bloem et al. 2016). Compared to inorganic and scientifically approved chelating agents, EDTA is more effective, safe for the environment, and biodegradable when it comes to enhancing the solubility, absorption, and stability of metals. According to García et al. (2017), EDTA was used by many previous researchers to improve the accumulation and metal transfers in plants when grown in heavy metals contaminated soil.

Research on the potential of Malaysian native bamboo and the potential of other soil conditioners such as bamboo biochar and EDTA in reducing soil heavy metals contaminants however is unknown. Thus, we aimed to investigate the effect of *D. asper* (Buluh Betong) a native Malaysian bamboo species with the additional application of bamboo biochar and EDTA in phytofiltering heavy metals from the mining soils at Chini watershed. This study has two objectives; to investigate the growth and heavy metal uptake of *D. asper* grown in the mining soil of Tasik Chini with several applications of bamboo biochar and EDTA and to assess the reduction of heavy metals in the contaminated soil after growing *D. asper* and with or without soil conditioner (bamboo biochar and EDTA).

We hypothesised that bamboo (*D. asper*) is able to tolerate heavy metals stress conditions and with the application of soil conditioners such as biochar and EDTA, it may improve metal uptake, reduce soil heavy metal concentration, and thus improve the soil fertility. The findings of this study will benefit the stakeholders and government agencies in managing and restoring the mining soil of Tasik Chini in the future.

MATERIALS AND METHODS

Study plant

Dendrocalamus asper Schult. (Backer) is one of the most widely cultivated commercial species of native bamboo in Malaysia. *D. asper* or Buluh Betong belongs to the Poaceae family, and it is a multipurpose tropical clumping bamboo with high economic value. In Malaysia, *D. asper* has been utilized in making paper, handicrafts, musical instruments, furniture, and utensils (Mustafa et al. 2021). Therefore, *D. asper* was selected as the study plant material due to its high commercial values compared to other native bamboo species. *D. asper* was purchased from Felda Global Ventures, Pahang.

Sampling site

Mining soil was collected at Bukit Ketaya (3°24’50.1”N, 102°55’28.7”E), Chini Watershed, Pahang (Figure 1). The soil was collected at the depth of 0–30 cm for physicochemical analyses and the pot experiments in the glasshouse. The soil samples were kept and air dried at the Faculty of Agriculture, Universiti Putra Malaysia (UPM) and the soil physicochemical analysis was analysed before the experiment.

Soil physicochemical analysis

The soil samples were sieved to 2 mm to conduct general analyses such as pH, EC, CEC, organic matter, and heavy metals concentration, while the rest was sieved to 10mm for pot experiment. The collected soil from the study site was analysed for soil pH using a soil:distilled water ratio of 1:2.5 and measured using a pH meter. The electrical conductivity (EC) was measured using an EC meter. The percentage of C, N, total C, and soil organic matter were measured using a CNS analyser. After the aqua regia extraction method, the heavy metal elements such as Cd, Fe, As, Pb, Cr, and Al were determined using a Microwave Plasma - Atomic Emission Spectrometer.

Pot experiments

D. asper was grown in the contaminated soil collected from the Chini watershed under various treatments which included the addition of bamboo biochar (BB) and/or Ethylenediaminetetraacetic (EDTA), control by only growing *D. asper* without any addition of soil conditioner and blank which was growing *D. asper* in the uncontaminated soil from UPM (Table 1).

Table 1 The treatment of growing D. asper under BB +/- EDTA for the experiment

Label	Treatments
Blank	Bamboo + uncontaminated organic soil
Control	Bamboo + Mining Soil
T1	Bamboo + Mining Soil + Bamboo biochar
T2	Bamboo + Mining Soil + EDTA
T3	Bamboo + Mining Soil + Bamboo biochar + EDTA

T = treatment

The experiment was conducted at the greenhouse in Faculty of Agriculture, UPM. Each pot contains an individual bamboo, and each treatment consists of three replicates and was arranged according to a complete randomized design (CRD). A total of 15 individuals of the 3-month-old bamboo were used in these experiments and with/without the addition of 3% bamboo biochar and/or 100 ml of 2 mM EDTA each pot was used (Table 1). The mixed soils were ground and put in plastic pots containing about 2 kg (dry weight) of soil.

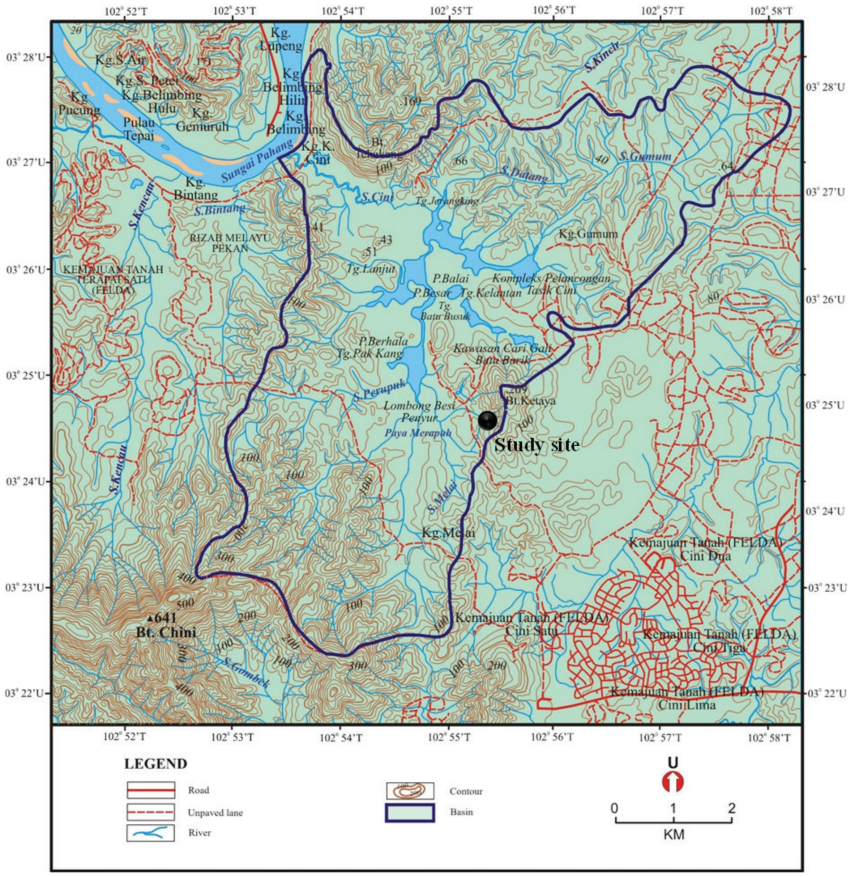

Figure 1 Location of soil sampling at Bukit Ketaya, Chini Watershed, Pahang. (Source: Department of Geography UKM)

The plant height, leaves numbers and relative growth rate of *D. asper* were measured during the experiments. The plants were harvested after 100 days of planting (Table 2). Some soil and plant parts were kept for chemical analysis.

Foliar and soil metals concentration analysis

The plant materials and soil were analysed to determine the concentration of metal elements Cd, Cr, As, Fe, Al, and Pb using MP-AES. The total Carbon (C) and Nitrogen (N) were determined using a CNS analyser. The heavy metals concentrations were analysed before and after treatment. All the metal concentrations were expressed in mg kg^{-1} dry mass. The soil pH was determined using a soil:distilled water ratio of 1:2.5 and measured using a pH meter. The electrical conductivity (EC) was measured using an EC meter.

Bioconcentration factor, translocation factor, and percentages of removal efficiency

The bioconcentration factor (BCF) was determined as the ratio of heavy metal concentration in tissues to heavy metals in the nutrient solution using the following formula:

$$\text{BCF} = \frac{\text{Heavy metals concentration in plant tissues}}{\text{Heavy metal concentration in soil}}$$

Translocation factor (TF) was determined by estimating the concentration of heavy metals in one part of the plant to the other parts as follows:

$$\text{TF} = \frac{\text{Heavy metals concentration in leaves}}{\text{Heavy metals concentration in roots}}$$

The percentages of removal efficiency (RE) were determined following Lazo et al. (2022):

$$RE = \frac{(Ci - Cf)}{Ci} \times 100\%$$

where, Ci and Cf were the initial and final concentrations of the elements in mining soil respectively.

Statistical analysis

One-way analysis of variance at $p \leq 0.05$ was used to compare variables between and within groups using the F test for statistical significance. Statistical analyses were performed using R version 4.2.3. All values reported were the means of three replication samples. Data means were tested at significance levels of $p < 0.05$ with one-way analysis of variance.

RESULTS

Plant growth

We found that Treatment III (T3), had the highest relative growth rate (RGR) in terms of height and final dry mass (g) among all treatments (Figure 2, 3 and 4). However, there were no significant differences were observed among these treatments (p>0.05).

Heavy metals concentration in *D. asper*.

Heavy metals concentrations of Cd, Fe, As, Pb, Cr, and Al were significantly differed among treatments (p<0.05). The rank of total metal concentration in all treatments in *D. asper* was Al > Fe > Pb > As > Cr > Cd. The metal concentration of Cd, Fe, As, Pb, Cr, and Al was the highest in T3 compared to other treatments (Figure 5). The concentrations of heavy metals in the plant parts are shown in Table 3.

Soil physicochemical analyses before and after treatment

After 100 days of planting, T3 recorded the highest value of pH, EC, soil organic matter (SOM), CEC, and C compared to other treatments (p<0.05). A similar trend was observed on soil heavy metals Cd, Fe, As, Pb, Cr, and Al as T3 has the highest concentration (mg kg^{-1}) among other treatments (p<0.05) (Table 3).

Phytoremediation factor

Treatment III (T3) had the highest value of BCF among other treatments (p<0.05) while the highest TF value was Treatment II (T2) (p<0.05) (Table 4). Nevertheless, T3 had also the highest percentage of removal efficiency (RE) compared to other treatments (p<0.05). The trend of soil and plant heavy metals distribution and growth is explained by the principal component analysis (PCA) (Figure 6). The PCA displayed a first axis defining 73% of the variance, and the first three PC axes cumulatively explained 100% of the variance (Table 5). The first PC axis was shown to have a significant positive association (p>0.05) with variation in RGR plant height, final dry mass, Cd, Fe, As, Pb, Cr, soil Cd, soil Fe, soil As, soil Pb, soil Cr, soil pH, and soil EC. The second PC axis was associated with variation in plant growth, final dry mass, Fe, As, Pb, Cr, Al, soil pH, and soil EC (p<0.05).

DISCUSSION

Dendrocalamus asper was tolerant to high concentrations of heavy metals in this study. Besides bamboo (Singh et al. 2021a) forest, or grazing land, leading to the overall loss of production. The eco-rejuvenation of such degraded lands in practice can largely be considered as ecosystem restoration or the reestablishment of the capability of the land to capture and retain its fundamental resources. Eco-rejuvenation is the biotechnological approach by which a degraded ecosystem can be rejuvenated to its top successional stage. An important goal of sustainable biodiversity development on degraded land in rural areas is to accelerate natural successional processes (above- and below-ground biomass, there are other several plant species such as *Jatropha curcas* (Maryam et al. 2015, Mingyuan et al. 2020) economical viable crops with environmental co-benefits, like phytoremediation, are preferred. In this study, Jatropha curcas was evaluated for its growth performance in bauxite mine soil. Topsoil and exposed subsoil were sampled from a bauxite mine at Bukit Goh, Kuantan and used for growing J. curcas for 90 days under greenhouse conditions. The soil physicochemical properties, plant growth parameters (increase in number of leaves, plant

Table 2 Mean ± SE of physicochemical of the soil before and after planting with *D. asper* for 100 days under different treatments. The list of treatments can be referred in Table 1

Soil samples	pH	EC (µS cm^{-1})	Soil Organic Matter (%)	Total Organic Carbon (%)	CEC (cmolc kg^{-1})	Cd (mg kg^{-1})	Fe (mg kg^{-1})	As (mg kg^{-1})	Pb (mg kg^{-1})	Cr (mg kg^{-1})	Al (mg kg^{-1})
Before planting											
Organic soil (Blank)	5.01±0.18	32.70±0.2	5.50±0.3	3.19±0.17	2.80±0.00	0.00±0.0	41182.50±5792.5	297.50±37.5	40±15	92±22	40282.50 ± 16867.5
Mining soil	3.53±0.42	29.59±0.81	3.80±0.6	2.20±0.35	2.30±0.50	15.0±1.0	150355.00±11870	537.50±12.5	4172.50±1052.5	277.50±152.5	59552.50 ± 16697.5
After planting											
Blank	4.50±0.45[a]	78.30±3.30[a]	4.0±0.0[a]	2.32±0.0[a]	3.55±1.55[a]	0.00±0.00[b]	34930.00±845.0[c]	287.00±31.0[b]	38.00±3.0[c]	88.00±8.0[b]	38511.00 ± 3089.0[a]
Control	4.49±0.19[a]	41.85±1.05[b]	4.9±0.7[a]	2.84±0.41[a]	4.15±0.05[a]	15.17±1.98[a]	127488.50±1861.5[a]	467.00±74.0[ab]	1540.00±165.0[b]	158.50±3.5[a]	55798.50 ± 13473.5[a]
T1	4.35±0.12[a]	89.85±8.95[a]	5.6±0.0[a]	3.25±0.0[a]	4.90±2.30[a]	15.25±1.00[a]	106788.00±2272.0[ab]	539.00±14.0[ab]	1990.00±11.0[b]	140.50±9.5[ab]	39620.00 ± 3770.0[a]
T2	4.49±0.78[a]	41.95±4.75[b]	3.9±0.3[a]	2.26±0.17[a]	1.50±0.04[a]	14.06±0.94[a]	116635.50±685.0[ab]	649.00±1.0[a]	3759.00±214.0[a]	141.00±16.0[ab]	40364.50 ± 4694.5[a]
T3	5.52±0.20[a]	82.30±1.60[a]	5.3±0.3[a]	3.07±0.17[a]	3.35±1.55[a]	16.25±1.03[a]	97405.00±10310.0[b]	573.00±73.0[a]	4045.00±100.0[a]	164.50±11.5[a]	38710.50 ± 1105.5[a]

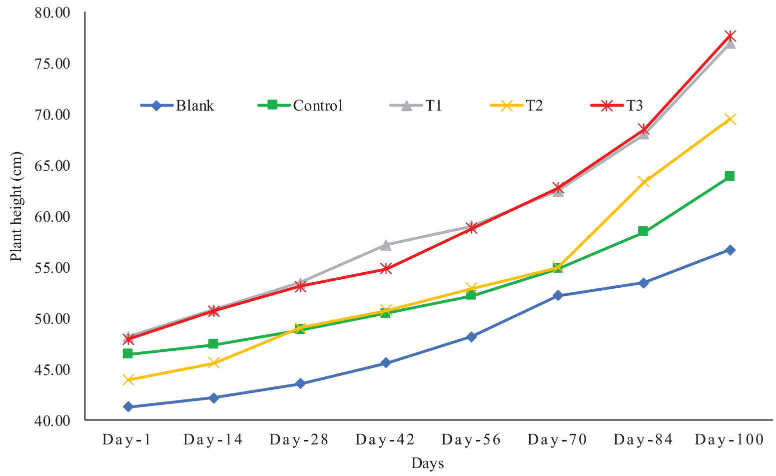

Figure 2 The plant height (cm) of *D. asper* after 100 days of planting under different treatments. The list of treatments can be referred in Table 1

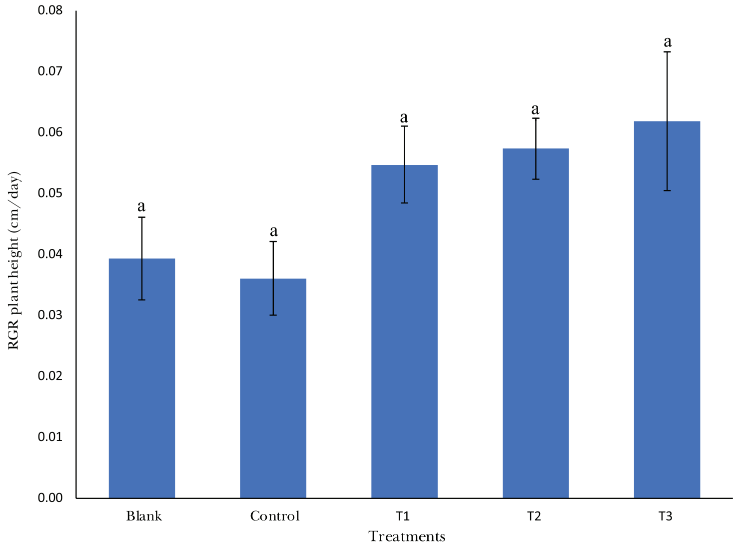

Figure 3 The relative growth rate (RGR) *D. asper* grown for 100 days under different treatments. The list of treatments can be referred in Table 1

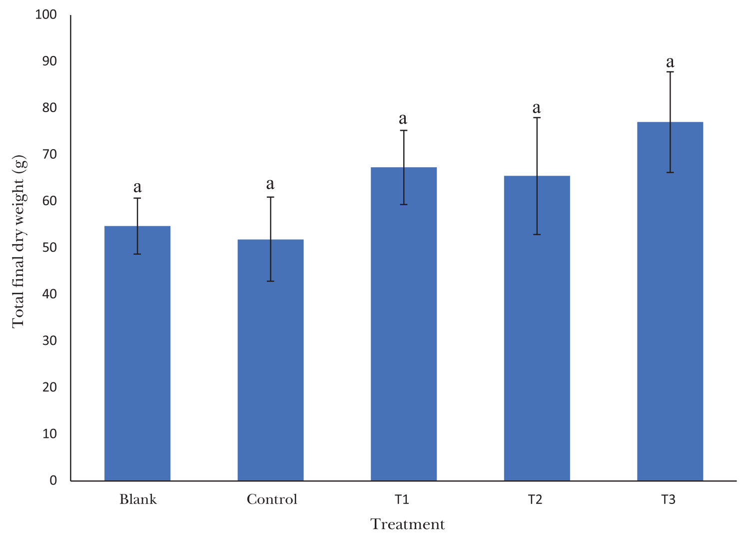

Figure 4 Total final dry weight of *D. asper* after grown under different treatments after 100 days of planting under different treatments. The list of treatments can be referred in Table 1

Table 3 The different percentages of heavy metals concentration in leaves, stems and roots of *D. asper* under T3 when compared with the control.

Treatment	Concentration of heavy metals in leaves (mg/kg)					
	Cd	Fe	As	Pb	Cr	Al
Bamboo + Tasik Chini soil + Biochar + EDTA	0.80	416.00	90.00	1410.00	20.00	750.00
Percentage compared to Control	73%	27%	34%	46-fold	67%	37%
Treatment	**Concentration of heavy metals in stems (mg/kg)**					
	Cd	Fe	As	Pb	Cr	Al
Bamboo + Tasik Chini soil + Biochar + EDTA	0.85	672.00	87.00	758.00	10.00	1384.00
Percentage compared to Control	40%	4-fold	3-fold	26-fold	70%	4.7-fold
Treatment	**Concentration of heavy metals in roots (mg/kg)**					
	Cd	Fe	As	Pb	Cr	Al
Bamboo + Tasik Chini soil + Biochar + EDTA	3.00	2262.00	94.00	1012.00	52.00	5964.00
Percentage compared to Control	90%	65%	24%	24-fold	1.1-fold	1.5-fold

height, and basal diameter, *Alnus nepalensis* (Wang et al. 2015), *Melastoma malabathricum* (Mahmud et al. 2024, Saberi et al. 2024) and other invasive plant species (Singh et al., 2021b) showed high tolerance to heavy metal stress conditions. Plants have eventually developed specific defense mechanisms against the stress caused by heavy metal pollution which include efflux pumps, cell sequestration, compartmentalisation, binding of heavy metals in various structures, and/or phytochelation, which produces potent ligands (Hossain et al. 2012).

Growing *D. asper* with the addition of biochar and EDTA has shown a better growth rate and metal uptake and this has frequently been observed that biochar application to soil improves soil fertility and plant development (Wang et al. 2019). Similarly, Rathika et al. (2021) reported that the combination of biochar and EDTA may significantly enhance the growth of *Brassica juncea*. In addition to its ability to absorb and immobilize contaminants in soils, biochar's distinctive porous structure and abundance of oxygen-containing functional groups on the surface also serve as a soil conditioner, providing nutrients that promote plant growth and retain nutrients, improves soil's physical and biological properties, and makes them useful in adsorbing heavy metal ions on its surface (Rathika et al. 2021).

According to Wang et al. (2019), biochar may enhance the soil pH and organic matter since they have higher properties of pH and carbon content which were useful for soil fertility. Besides, biochar retains nutrients and improves the physical and biological properties of soil (Lehmann & Rondon 2006, Wang et al. 2019). Our finding is similar to Van Poucke et al. (2018) peat or lime as a reference. Amendments were mixed with the contaminated soil at a 2 or 4% ratio (w:w, and Fellet et al. (2011) also found that the pH, CEC, and organic matter soil from mine tailing increased significantly with the addition of biochar. According to Wang et al. (2019), the addition of bamboo biochar has increased the accumulation of heavy metals in moso bamboo. The observation may be due to the reduction in soil pH which has boosted mobility of heavy metals. According to Mohamed et al. (2015), the highly efficient bamboo biochar in reducing the solubility and availability of heavy metal in the selected soil might have resulted from the significant increases in soil pH and CEC. These findings support the research by Houben et al. (2013), which indicated that heavy metal concentration was significantly lower in the presence of biochar compared to the control, and the increase of biochar rates reduced the heavy metal extractability. Due to

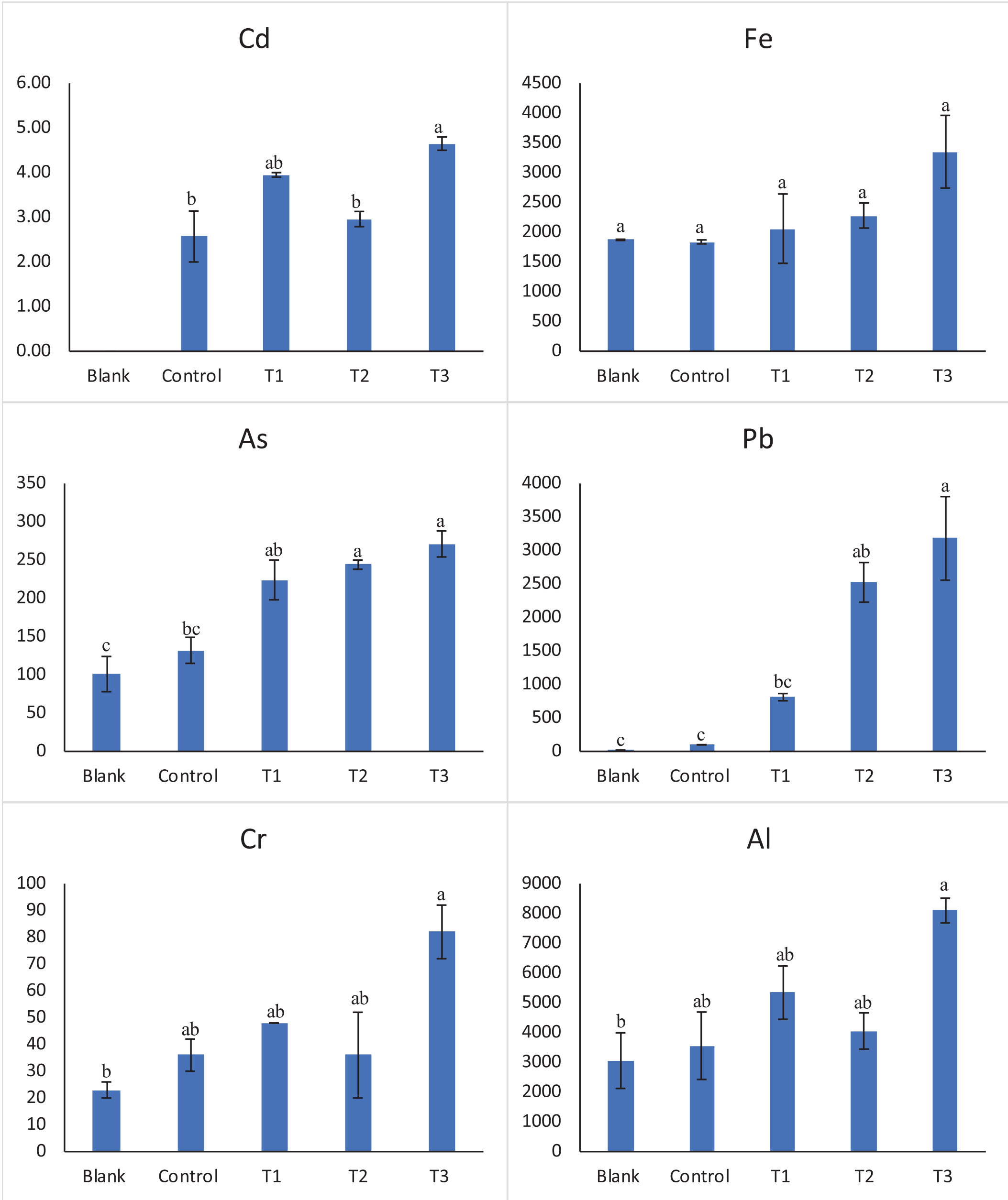

Figure 5 Total metals concentration (mg/kg) in *D. asper* after 100 days of planting under different treatments. The list of treatments can be referred in Table 1

the liming effect of miscanthus straw biochar on the soil, Houben et al. (2013) found that the concentrations of heavy metals in $CaCl_2$ extracts decreased by 14%, 44%, and 71% in soil incorporated with 1%, 5%, and 10% of biochar, respectively.

Numerous studies have confirmed that the increase in soil pH is one of the important reasons explaining the reduction of heavy metals mobility by biochar (Méndez et al. 2012, Zheng et al. 2012). An increase in soil pH may facilitate the immobilisation of heavy metals by causing them to precipitate in mobile, non-soluble forms such as hydroxides, carbonates, phosphates, and oxides, which would result in greater solubility decreases. Furthermore, elevated soil pH played a key role in enhancing the negative charges of both soil and biochar, leading to notable advancements in metal adsorption (Naidu et al. 1994, McBride et al. 1997, Bolan et al. 2003, Bradl 2004, Houben et al. 2013). Increases in soil pH, SOC, and CEC after biochar application may help lower the extractability of heavy metals from the soil by

Table 4 Bioconcentration Factor (BCF), Translocation Factor (TF), and Percentage of heavy metal removal efficiency (RE) of *D. asper* after 100 days under different treatments. The list of treatments can be referred in Table 1

Treatments	Cd	Fe	As	Pb	Cr	Al
	Bioconcentration factor (BCF)					
Blank	0.00	0.04	0.24	0.53	0.15	0.07
Control	0.12	0.01	0.23	0.03	0.15	0.05
T1	0.24	0.01	0.23	0.22	0.30	0.12
T2	0.14	0.01	0.21	0.50	0.19	0.09
T3	0.26	0.02	0.31	1.17	0.63	0.19
	Translocation factor (TF)					
Blank	0.00	0.31	0.76	0.04	0.90	0.20
Control	0.31	0.24	0.45	0.71	0.67	0.20
T1	0.28	0.29	1.00	0.92	0.43	0.16
T2	0.41	0.20	0.92	1.84	0.60	0.18
T3	0.27	0.18	0.96	1.39	0.38	0.13
	Percentage of heavy metal removal efficiency (RE) after 100 days of treatment (%)					
Blank	0.00	19.72	37.48	43.75	29.35	11.98
Control	16.00	16.43	37.67	65.49	55.86	12.27
T1	24.67	30.34	41.40	71.72	66.67	42.44
T2	26.00	23.94	24.65	70.40	62.16	39.02
T3	22.67	37.44	43.72	79.27	70.27	48.60

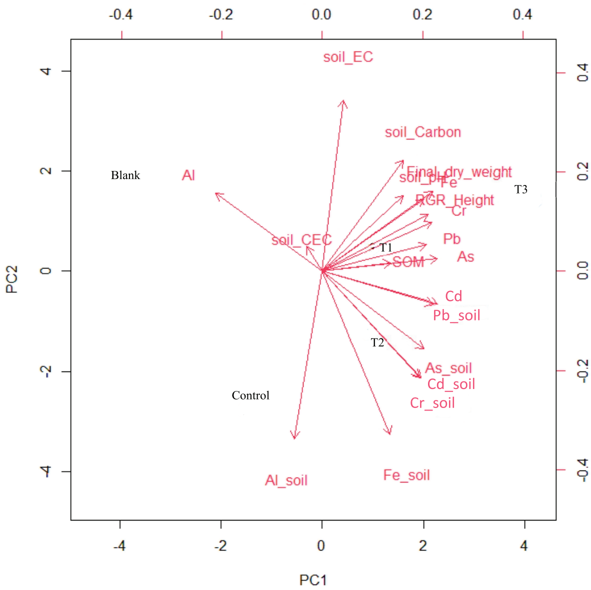

Figure 6 Biplot of scores for principal component axes (PC) 1 and 2 from the principal component analysis of bamboo in mining soil with the addition of biochar and EDTA (growth, foliar heavy metals concentration, and soil physicochemical analysis) of *D. asper*. PC1 and PC2 accounted for 57.3% and 77.8% of the total variation, respectively. The arrows show the loadings of each variable on the first two PC axes

Table 5 Summary statistics of PCA axis related to growth and heavy metals concentration in *D. asper* after 100 days of planting

Importance of components	PC1	PC2	PC3	PC4
Eigenvalue	10.879	3.899	3.101	1.121
Percent of Variance (%)	5.726	2.052	1.632	5.901
Cumulative Proportion (%)	57.257	77.777	94.099	100.0
Loadings of parameter properties				
RGR Height	0.592	0.192	-0.188	0.190
Final dry mass	0.614	0.269	-0.072	0.068
Cd	0.648	-0.109	0.151	0.069
Fe	0.568	0.243	-0.110	-0.254
As	0.643	0.042	-0.141	0.155
Pb	0.580	0.090	-0.332	-0.062
Cr	0.612	0.166	0.130	-0.198
Al	-0.594	0.262	-0.190	-0.038
Cd soil	0.553	-0.361	0.141	0.054
Fe soil	0.379	-0.549	0.081	0.084
As soil	0.564	-0.261	-0.188	0.192
Pb soil	0.619	-0.110	-0.251	-0.009
Cr soil	0.540	-0.357	0.144	-0.137
Al soil	-0.158	-0.564	0.235	-0.246
Soil pH	0.451	0.253	-0.044	-0.435
Soil EC	0.118	0.577	0.312	0.122
Soil CEC	-0.088	0.084	0.665	0.039
Soil organic matter	0.383	0.028	0.557	0.034
Soil Carbon	0.452	0.375	0.334	0.051

generating some new exchangeable sites for metal adsorption.

EDTA is an effective chelating agent for heavy metals in soil and increases the solubility of heavy metals for plant uptake (Shahid et al. 2014)several techniques, including phytoremediation of heavy metals, have been extensively studied. In spite of significant recent advancement, ethylene diamine tetraacetic acid (EDTA. Therefore the combination application of biochar and EDTA are complementary to each other since EDTA enhances the availability of contaminants for plant uptake, while biochar helps to stabilise and immobilise these contaminants in the soil (Rathika et al. 2021). The high concentration of metals in plants and their availability in the soil are important factors in the phytoremediation process' effectiveness in metal-contaminated soils, thus EDTA plays a vital role in enhancing the transport of metals (Amin et al. 2018). Growing *D. asper* with bamboo biochar and EDTA addition has shown a better BCF and TF value indicating it is a suitable phytoextraction, particularly Pb. Other elements (Cd, Fe, Cr, As, and Al) have TF < 1 and may considered suitable for phytostabilisation (Table 4). Furthermore, under the same treatment, it has higher removal efficiency percentages indicating that growing *D. asper* with the addition of bamboo biochar and EDTA is a promising treatment to remove soil heavy metal contaminants.

CONCLUSIONS

Dendrocalamus asper is resilient to heavy metal soil concentration and capable of stabilising the heavy metals in the soils. No adverse effects on the growth of *D. asper* were observed when planting in the contaminated mining soil. *D. asper* can be a good phytoremediator since it can stabilize and reduce soil contaminants. The additional application of bamboo biochar and EDTA was found to be promising in assisting the phytoremediation process. Further research in in-situ is required to investigate the efficiency of the synergistic effect of *D. asper* with the soil conditioners in reducing soil contaminants and improving soil fertility at the field site in the future. The right approach of planting bamboo and other trees with the addition of soil conditioners may benefit forest restoration activities and improve the soil fertility in the ex-mining soil at the Chini watershed.

ACKNOWLEDGEMENTS

We acknowledged the Research Management Centre (UPM), Universiti Putra Malaysia Grant (GPM-IPM/2020/9690400), Tadom Hill Resort Sdn. Bhd. (6300421-12038) and UKM PPTC (6300414) for the funding and support throughout our research.

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