

PHYTOEXTRACTION OF CADMIUM BY *Pteris vittata* L. AND *Pteris ensiformis* BURM. F. (FERNS) GROWN ON CADMIUM CONTAMINATED SOIL IN OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE

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ABSTRACT

Cadmium pollution is increasingly becoming a major world problem. Therefore, this study investigated the potentials of *Pteris ensiformis* and *Pteris vittata* in phytoextracting cadmium (Cd) in the Cd contaminated soil. The two studied species were collected from fern garden at the Natural History Museum on Obafemi Awolowo University campus, Ile-Ife, Nigeria. The treatments used were; CT: control plants that were not exposed to Cd contamination, A: plants cultivated on soil contaminated with 50 ppm, B: 100 ppm, C: 150 ppm, and D: 200 ppm of Cd. The bioaccumulation factor (BAF), transfer factor (TF) and impacts on growth and biomass indices of roots and fronds were determined to assess and compare the phytoextraction potentials of the two plants. The study revealed that, Cd concentrations significantly affected the growth and biomass parameters with the effects being less significant on *Pteris vittata* compared to that of *P. ensiformis*. The BAF and TF increased with increasing levels of cadmium concentrations in the plants. *P. vittata* and *P. ensiformis* had BAF and TF values less than one which implies that they did not effectively accumulate Cd from the soil. *P. vittata* had higher BAF and TF which indicates it accumulated more Cd than *P. ensiformis*. Therefore, *P. vittata* has better Cd phytoextraction potentials than *P. ensiformis*.

Keywords: Bioaccumulation factor, transfer factor, cadmium, fernlets, growth parameters, phytoextraction, treatment.

INTRODUCTION

Pteris is a genus belonging to the family Pteridaceae which is a large family comprising over 50 genera, distributed throughout the world. *Pteris* is found in different ecological niches including terrestrial, aquatic, epiphytic, xeric and hot desert (Sharpes *et al.*, 2010) with over 300 species found mostly in the tropics. *Pteris vittata* L. is a perennial, evergreen, herbaceous, medicinal plant with an erect rhizome. It has been cultivated as an ornamental fern and is useful in pollution control schemes as arsenic and lead hyper-accumulator plant (Oloyede *et al.*, 2013; Yusuf *et al.*, 2018). As a result, the plant has the potentials to be useful in phytoextraction in certain areas. *Pteris ensiformis* Burm F. is a perennial, herbaceous plant with an erect rhizome; alternate, coarse and leathery leaflets. In Nigeria, it is being cultivated as an ornamental plant and also useful for landscaping (Oloyede, 2012; Bamigboye *et al.*, 2020).

Heavy metals contamination of soils is increasingly becoming a serious challenge facing

the world. Cd is a silver-white, glossy heavy metal and solid at room temperature (Goyer *et al.*, 2004). Anthropogenic sources for Cd pollution are mining, smelting, sewage sludge, NiCd batteries, plating, pigments, plastics, wastewater, irrigation, vehicular emissions, and agrochemicals. Smelters' burning fossil fuels like coal, oil, incinerating and municipal wastes, like plastics and nickel-cadmium batteries among others are the main cradles of airborne Cd (ATSDR, 1999). About 23,000 metric tons of Cd were produced globally in 2016 (excluding the USA) (USEPA, 2020). Due to their geochemical similarities, during the smelting of Zn, significant amounts of Cd are discharged into the atmosphere. Dust that is Cd-rich is released into the air during the manufacturing of Zn, and after a while, it settles in the soil (Thomas *et al.*, 2009; Roy and McDonald, 2015). Powdered Cd burns and emits poisonous and corrosive gases but solid Cd is inflammable. Cd also slows shoot and root growth, and lowers nutrients uptake (ATSDR, 1999; Khan *et al.*, 2015). In human beings, Cd causes bone degeneration, and

nephron toxicity resulting in decreasing glomerular filtration rate (Ozyigit and Genc, 2020). Continuous exposure to Cd can lead to renal tubular impairment, osteoporosis, osteomalacia, glycosuria and abnormal calcium metabolism (Thomas *et al.*, 2009). Being exposed to Cd causes cardiovascular disease, infections, anosmia, emphysema, brain infection and proteinuria (Ramakrishnan *et al.*, 1995). Furthermore, it has been reported that Cd is carcinogenic in humans and can be hazardous even at low concentrations (IARC, 2012). Numerous remediation of soil technologies that have been used included phytoextraction, botanical extraction, solidification, stabilization and phytoremediation approaches. Heavy metals constitute an imminent danger to the ecosystem due to their non-biodegradability with the eventual biological accumulation in living tissues (Akinbile *et al.*, 2016). Heavy metal-contaminated soils and water in mining areas can be cleaned by phytoextraction using plants that can bioaccumulate heavy metals in their tissues (Fu *et al.*, 2008).

The removal, transformation, or assimilation of harmful compounds from the soil, sediments, ground, surface water, and air is known as phytoextraction (Susarla *et al.*, 2002). Sulatri and Tampubolon (2019) reported the phytoextraction of Cd and its relationship to essential oil production by aromatic plants. *Carduus nutans* and *Phlomis* species have been reported as suitable bioaccumulator plants for phytoextraction of Cd-contaminated mining soils by Mahmut *et al.* (2022). The severe Cd toxicity to plants and animals has made environmentalists pay close attention to soil contamination with heavy metals. *P. vittata* was reported to be a phytoremediator of arsenic and lead in the contaminated soil and water while *P. ensiformis* was a non-phytoremediator of arsenic (Oloyede *et al.*, 2013; Yusuf *et al.*, 2018). Cd is a micro-element that is not necessary for life and is not involved in the growth and developmental processes in both plants and animals (Kamran *et al.*, 2019). Therefore, there is a need to assess the Cd phytoextraction potentials of *P. vittata* and *P. ensiformis*. Thus, this study investigated the phytoextraction potentials of Cd from Cd-contaminated soil by these two species and the effects of the Cd contaminations on their

vegetative growth parameters.

METHODOLOGY

Study Site

The research was conducted in the Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria. Experimental fern plants (*Pteris vittata* and *Pteris ensiformis*) were collected from the fern garden at the Natural History Museum, O.A.U., and cultivated in the Department of Botany (O.A.U.), Ile-Ife (Latitude 07° 30.992' N, and Longitude 04° 31.598' E). Identification of the ferns was carried out at the IFE herbarium with Voucher specimen numbers (*P. vittata*: IFE 18990; *P. ensiformis*: IFE 18991).

Preparation of the Soil

Randomly collected topsoil samples (0-20 cm) from the back of the Natural History Museum were air-dried, and filtered with 2.0 mm wire gauze mesh to eliminate debris and the physical properties were determined following a standard procedure (Gee and Bauder, 1986). Sixty plastic pots (15 cm x 18 cm) perforated at the base were filled with 2.0 kg of the prepared topsoil. For each of the fern species, five pots labeled as CT (control), A, B, C, and D were prepared. The pots except the control were treated with different CdCl₂ concentrations (i.e. 50 ppm, 100 ppm, 150 ppm, and 200 ppm respectively). A total of four Cd concentrations and controls were established for each of the plants in a completely randomized design. Each treatment with each fern was replicated six times and left for two days to allow even mixture or equilibrium.

Fernlets Transplanting

Healthy fernlets of *P. vittata* and *P. ensiformis* were collected from vegetatively propagated parent plants and transplanted into the prepared pots containing topsoil treated with the different Cd concentrations. The experiment was monitored for 12 weeks after transplanting while 50 mL of water was used for watering the soil daily to supply water for the growing plants.

Growth Measurement and Analysis

Growth was monitored weekly in each of the treatments throughout the period of the study. Terminal leaflets' length and width, and the fronds' height were carefully measured with the

aid of a meter rule. The leaflet numbers per treatment per species were counted and recorded weekly. The ferns were then harvested at the end of the twelfth week and separating the shoot from the root. The roots were thoroughly washed, and oven-dried together with the shoots at 60 °C for 48 hours. The leaflet area was calculated from the data obtained from leaflet measurements using the formula: Leaflet Area (cm²) = L × W × K Where L = Length (cm), W = width (cm) and K = correction factor (2.325) (Osei-Yeboah *et al.*, 1983).

Chemical Analysis

Chemical analysis of some heavy metals contents (Tables 1 and 2) including Cd, present in the soil and the parent plants (control) was done using an Atomic Absorption Spectrophotometer (AAS), before the experiment. The dried shoots and roots of the experimental plants were ground. The ground shoots and roots, and the soil from each treatment were analyzed for Cd concentrations using AAS. The ratio of Cd concentrations in the shoots and roots to that in the soil (bio-concentration) and the ratio of Cd concentrations in the shoot to that of the root (the transfer factor) were determined after the experiment.

Data Analysis

The data that was generated was subjected to both descriptive and inferential statistics using Statistical Analytical System (SAS) version 9.1. One-way analysis of variance (ANOVA) was used to investigate the effect of Cd treatments on the

roots and fronds of the two plants while two-way ANOVA was used to determine the effects of the different Cd concentrations on vegetative parameters (frond height, leaflets numbers, length, width and area) and biomass (roots and fronds) of the fern species. Significant means among the treatments were separated using the Duncan Multiple Range Test at 0.01 and 0.05 alpha levels of probability.

RESULTS

Soil's Chemical Properties and Cadmium Concentrations of the Experimental Plants

The results of the elemental analysis of the heavy metal contents of the soil and the two fern species used in this research revealed that they were extremely low in Cd concentrations (Tables 1 and 2). Whereas the recommended threshold values for Cd are 0.80 PPM (FEPA, 1991), 0.002 - 0.5 PPM (Ediene and Umoetok, 2017), 1.40 – 39.00 PPM (USEPA, 2024) and 3.00 ppm (FAO, 2024). The pH of 6.12 was recorded for the topsoil which indicated a slightly acidic condition.

The Effects of Cadmium on Growth and the Biomass of *Pteris vittata*

Fronds' height

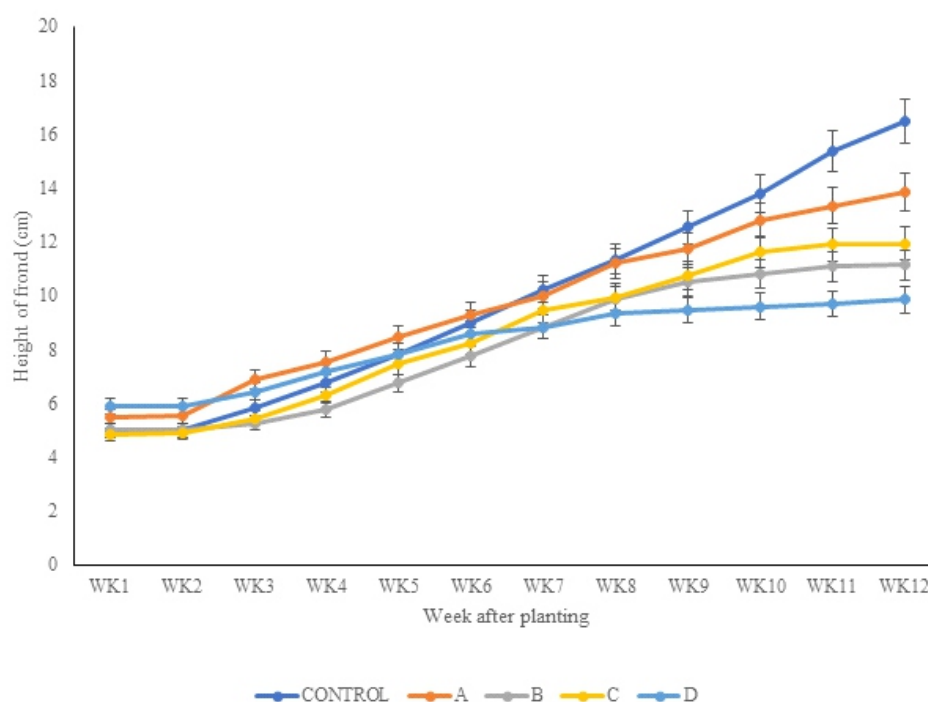
The mean fronds' height of *Pteris vittata* in the various Cd treatments are presented in Figure 1. No significant difference ($p \leq 0.05$) was recorded in the fronds' height among the treatments from weeks one to seven. However, a significant difference was recorded among the treatments from week eight till the end of the twelfth week.

Table 1: Chemical Properties of the Soil before the Experiment.

Heavy metals content	Values (ppm)
Organic Carbon	5.200
Magnesium	2327.100
Potassium	2610.000
Copper	0.042
Manganese	0.051
Zinc	0.081
Iron	0.109
Cobalt	0.035
Cadmium	0.021

Table 2: Cadmium Concentrations (ppm) in *Pteris vittata* and *Pteris ensiformis* before the Experiment.

Plant parts	<i>Pteris vittata</i>		<i>Pteris ensiformis</i>	
	Frond	Root	Frond	Root
Cadmium Concentrations (ppm)	0.004	0.006	0.003	0.004



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 1: The Effects of Cadmium Treatments on the Frond Height of *P. vittata*

No significant difference in frond height among treatments B, C, and D, was recorded at the end of the experimental period but, the mean frond heights of the control and treatment A were significantly higher ($p \leq 0.05$) compared to the other treatments, while treatment D had the lowest frond height with the mean value of 9.85 cm (Figure 1).

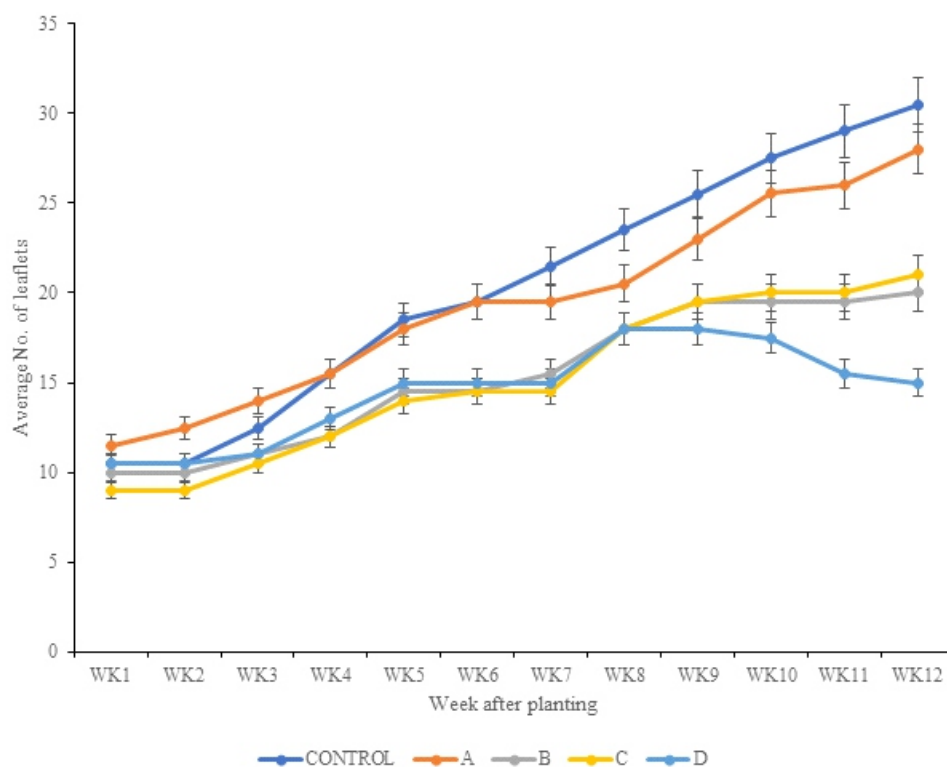
Leaflets number

The mean leaflet numbers in *P. vittata* under the various Cd treatments are presented in Figure 2. There was no significant difference among the treatments ($p \leq 0.05$) from week one to week five but there was significant difference ($p \leq 0.05$) among the treatments from week five till the end

of the experiment. The highest mean value was recorded in the control while, the lowest was recorded in treatment D.

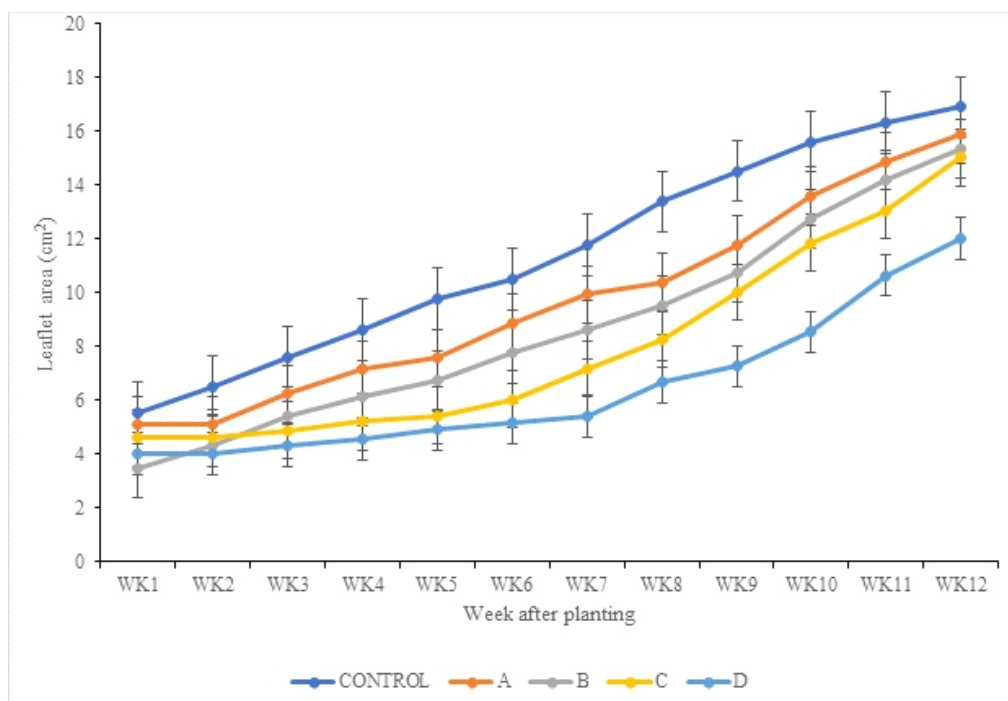
Leaflet area

Figure 3 shows the mean leaflet area of *P. vittata* grown at various Cd treatments. No significant difference ($p \leq 0.05$) in the leaflet areas among the treatments in the first seven weeks was observed. However, there was a significant difference among the treatments from week seven to week twelve. Control was significantly higher than other treatments with the highest leaflet area of 16.9 cm^2 whereas treatment D had the least leaflet area of 12 cm^2 .



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 2: The Effects of Cadmium Treatments on the Leaflets Number of *P. vittata*



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 3: The Effects of Cadmium Treatments on Leaflet Area of *P. vittata*

Shoot (frond) and Root Biomass

Table 3 shows the shoot and root biomass of *P. vittata*. A higher shoot biomass compared to the root biomass was recorded in all the treatments. The shoot and the root biomass were reduced with increasing Cd treatments. There was a significant difference ($p \leq 0.05$) in the mean shoot and root biomass among the treatments with treatments C and D having the lowest mean values.

Effects of Cadmium on Growth Parameters and Biomass of *P. ensiformis*

Fronds' height

The mean heights of *P. ensiformis* fronds in the various Cd concentrations are presented in Figure 4. There was no significant difference ($p \leq 0.05$) in frond heights among the treatments in the first three weeks but a significant difference was recorded from week four till the end of the

experiment. A significant difference in the mean frond heights between treatments A and B was recorded at the end of the experiment period, with the mean frond height of the control treatment being significantly higher ($p \leq 0.05$) than others. However, *P. ensiformis* in treatments C and D died in weeks 9 and 8 respectively before the end of the experimental period.

Leaflets numbers

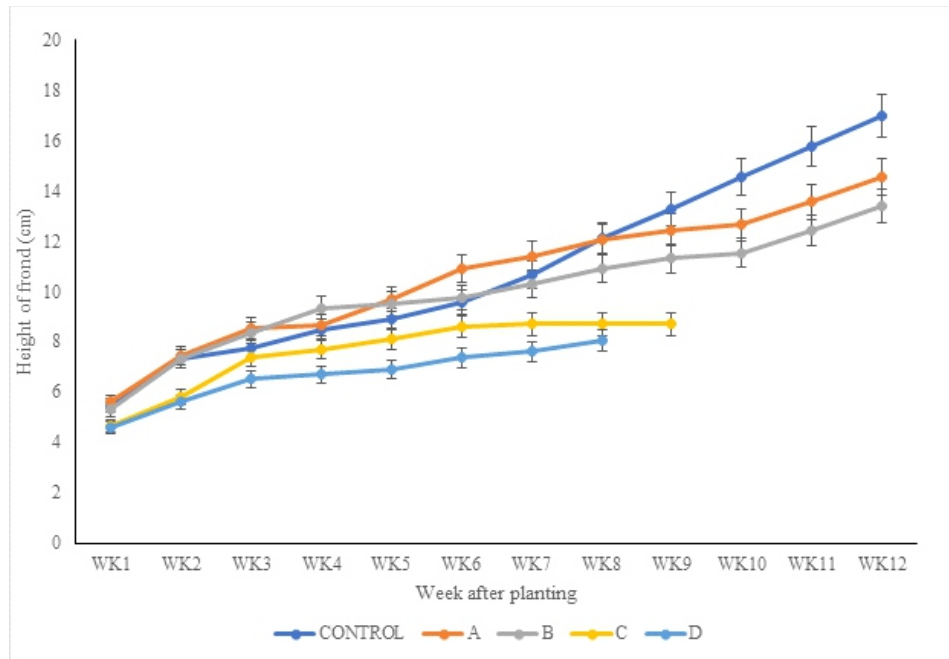
Figure 5 shows the mean leaflets number of *P. ensiformis* in the different Cd treatments. No significant difference in the mean leaflets number among the treatments ($p \leq 0.05$) was recorded from the first to the fifth week. At the end of the experiment, there was a significant difference ($p \leq 0.05$) in several leaflets among the treatments with control being the highest and followed by treatments A and B. The plants in treatments C and D died at weeks 9 and 8 respectively.

Table 3: The Effects of Cadmium treatments on the Biomass of *P. vittata* after 12 weeks.

TREATMENTS	FROND (SHOOT) (g)	ROOT (g)
CONTROL (CT)	8.20 ^a	5.09 ^a
A	8.09 ^a	4.99 ^a
B	7.89 ^a	4.90 ^a
C	7.40 ^b	4.50 ^b
D	7.28 ^b	4.35 ^b

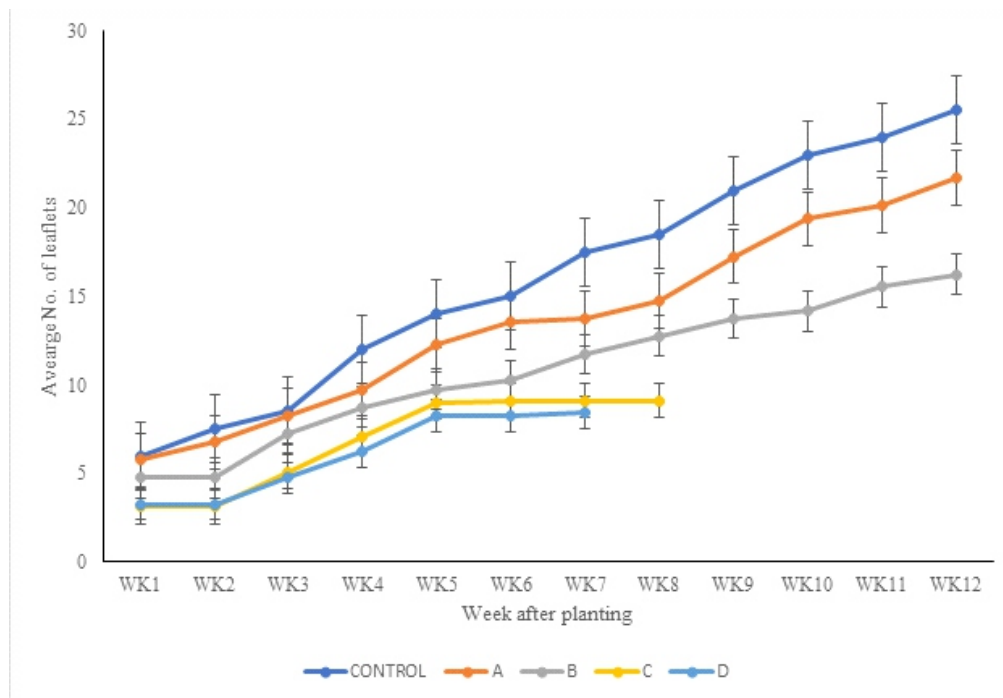
Values having the same superscript in a column are not significantly different ($p \leq 0.05$)

Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 4: The Effects of Cadmium Treatments on Frond Height of *P. ensiformis*



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 5: The Effects of Cadmium Treatments on the Leaflets Number of *P. ensiformis*

Leaflet area

Figure 6 shows the result of the effects of Cd treatments on leaflet areas of *P. ensiformis*. There was no significant difference ($p \leq 0.05$) in the mean leaflet area among the treatments in the first two weeks. However, a significant difference ($p \leq 0.05$) in the mean leaflets area was observed from the third week till the end of the experiment, with the control experiment having the highest mean value followed by treatments A and B. Plants subjected to treatments C and D died by weeks 9 and 8 respectively before the end of the experiment.

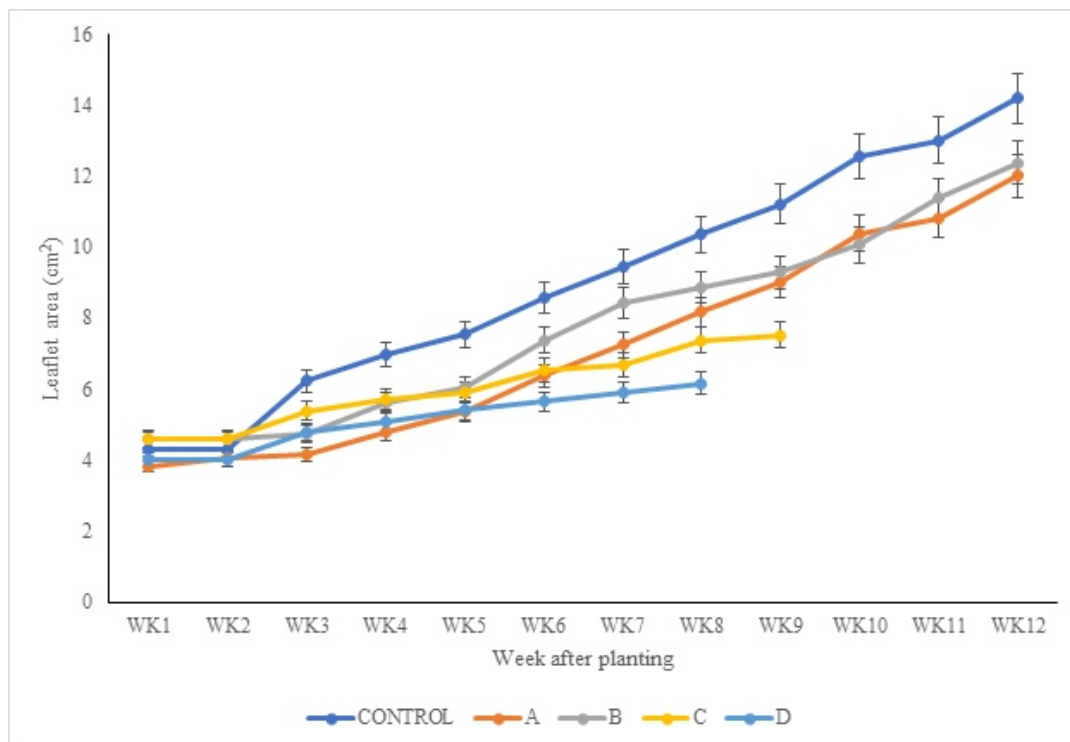
Fronde (shoot) and root biomass

The results of the experiment on the shoot and root biomass of *P. ensiformis* showed higher shoot biomass than the root biomass (Table 4). The mean shoot and root biomass decreased with increasing levels of Cd contaminations. There was a significant difference in the mean shoot and root biomass among the treatments ($p \leq 0.05$) with

treatments C and D having the lowest mean values for both shoot and root biomass which eventually withered away before the end of the experiments.

The ANOVA result (Table 5) showed that the frond heights, leaflet numbers, leaflet areas, shoot and root dry weights of *P. vittata* and *P. ensiformis* were significantly different at $p \leq 0.01$ and $p \leq 0.05$. The treatment at different concentrations ($p \leq 0.01$, $p \leq 0.05$) significantly affected the leaflet number, leaflet area, shoot weight, root weight and plant biomass of the two plants.

The treatments and the species interactions showed significant effects ($p \leq 0.01$, $p \leq 0.05$) on the mean frond heights, leaflets number and leaflet area of *P. vittata* and *P. ensiformis*. Meanwhile, treatment and species interactions showed no significant effect on the mean shoot and root weights and the plants' biomass at $p \leq 0.01$, $p \leq 0.05$.



Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Figure 6: The Effects of Cadmium Treatments on the Leaflet Area of *P. ensiformis*

Table 5: Summary of the ANOVA Result of the Effect of Different Cadmium Concentrations on Growth Parameters and Biomass of *P. vittata* and *P. ensiformis*

Source	Degree of freedom	Fronde heights	Number of leaflets	Leaflet area	Shoot dry weight	Root dry weight	Plant Biomass
Species	1	0.003**	0.04*	6.39**	0.006**	0.005**	0.003**
Treatments	4	0.11 ^{ns}	0.0002**	0.0086**	0.02*	0.04*	0.02*
Species × Treatments	12	0.02*	0.0005**	0.02*	0.12 ^{ns}	0.39 ^{ns}	0.21 ^{ns}

*, **: significant; ns: not significant at $p \leq 0.01$ and $p \leq 0.05$ respectively

Bioaccumulation and Transfer Factors

Shoot and root bioaccumulation factors (BAFs) for the two fern species increased with increasing levels of Cd concentrations (Tables 6 and 7). The lowest BAFs for both root and shoot of *P. vittata* were recorded in treatment A, while, the highest value was noted in treatment D. The lowest BAF for *P. ensiformis* was recorded in treatment A, while, the highest value was recorded in the treatment B. The transfer factor (TF) in *P. vittata* ranged between 0.4579 and 0.8733, with treatments A and D being the lowest and highest respectively. The TF in *P. ensiformis* ranged from 0.4794 in treatment A to 0.5000 in treatment B, while the plants in treatments C and D died before the end of the experiment.

DISCUSSION

Heavy metals become noxious to plants once they accumulate in the soil above the threshold level. They are also a potential threat to humans as a

result of their biomagnified effects along the food chains. In response to environmental stress to heavy metal contaminations, plants evolve physiological, morphological and metabolic changes as survival strategies. The expression of metal-induced functional and ultra-structural alteration causes visible signs of metal toxicity. These alterations at the cell, tissue, and organ levels are the outcome of toxic metals' direct interactions with the structural elements present in these locations (Singh and Sinha, 2004). Heavy metals have the potential to cause reductions in leaf size, the total leaf number, shoot biomass, stomata aperture, and inhibition of shoot growth, chlorosis and necrosis of the leaves there by causing decrease in photosynthetic activities of plants (Rai *et al.*, 2010; Ozyigit *et al.*, 2013). Growth parameters are good indicators of the growth performance of plants growing under normal, conducive, and favourable environmental conditions.

Table 6: Cadmium Bioaccumulation and Transfer Factors of *P. vittata* Grown in Cadmium Treated Soil.

Treatments	Transfer Factor	Bioaccumulation Factor	
		Fronds	Roots
Control	0	0	0
A	0.4579 ^a	0.0343 ^a	0.0749 ^a
B	0.5117 ^a	0.0528 ^a	0.0785 ^b
C	0.6726 ^b	0.1726 ^b	0.3373 ^a
D	0.8733 ^b	0.3212 ^a	0.3678 ^a

Values with the same superscript in a column are not significantly different ($p \leq 0.05$)

Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

Table 7: Cadmium Bioaccumulation and Transfer Factors of *P. ensiformis* Grown in Cadmium Treated Soil

Treatments	Transfer Factor	Bioaccumulation Factor	
		Fronds	Roots
Control	0	0	0
A	0.4794 ^a	0.0337 ^a	0.0702 ^a
B	0.5000 ^b	0.0486 ^b	0.0972 ^b
C	-	-	-
D	-	-	-

Values having the same superscript in a row are not significantly different ($p \leq 0.05$)

Legend: Control = 0 ppm, A = 50 ppm, B = 100 ppm, C = 150 ppm, D = 200 ppm

The results from this study revealed an inverse relationship between the Cd treatments and growth indices, because, as the level of Cd concentrations increased, growth parameters decreased. According to Vecchia *et al.* (2005), a retarded development in plants may be related to the lowered mitotic activity caused by Pd or Cd treatments. This is because Cd interferes with plants' ability to absorb, transport and utilize essential nutrients of great importance for regular growth and development (Das *et al.*, 1997). Cd inhibits the activities of nitrate reductase in the root which reduces nitrate absorption and its transit to the shoot via the root (Hernandez *et al.*, 1996). When compared to the control, *P. vittata* and *P. ensiformis* absorption of Cd had a negative influence on the frond height, leaflets number and leaflet area; thus, vegetative growth characteristics in the two plants decreased with increasing levels of concentrations.

This observation agreed with Yusuf *et al.* (2018) who observed a progressive decrease in frond heights, leaflet numbers and leaf areas of *P. vittata* and *Pityrogramma calomelanos* cultivated on Cd-contaminated soil, and Omosun *et al.* (2008) who noted a progressive reduction in the height, leaf numbers and leaf areas of *Amaranthus hybridus* grown in crude oil contaminated soil. On the contrary, Ogbo *et al.* (2009) reported the higher leaf area in crude oil-contaminated plants while investigating the phytoextraction potentials of *Paspalum scrobiculatum*. However, in this study, the decrease in growth indices resulted in the death of *P. ensiformis* and this agrees with Salt *et al.* (1995) who reported 100 ppm as the permissible limit of Cd in agricultural soil. This result thus showed that *P. vittata* had better phytoextraction potentials of

Cd than *P. ensiformis*.

Plant biomass has been reported as a reliable indicator for determining the growth performance of plants growing on heavy-metal contaminated soil. When Cd concentrations in the soil increase, plant biomass reduces (Hu *et al.*, 2012; Wang *et al.*, 2019). The dry weight of the roots and shoots of the two plants studied was reduced with increasing levels of Cd concentrations. This was due to high Cd accumulation which results in the death of *P. ensiformis*. This finding is similar to Oloyede *et al.* (2013) in which death was recorded for *P. ensiformis* at higher arsenic concentrations. Cd had greater negative impacts on the biomass of *P. ensiformis* than *P. vittata* which is an indication that *P. vittata* had better phytoextraction potentials of Cd than *P. ensiformis*. Roots were observed to show higher tolerance to Cd than shoots in both species, hence they accumulated more Cd. This is contrary to Xu *et al.* (2010) who reported greater BAF in the shoot of *P. vittata* when grown in three arsenic-spiked soils in the glass house. However, the findings of Nabeel *et al.* (2011) who reported higher BAF in the root than the shoot of *P. calomelanos* when grown in the soil contaminated with arsenic acid supported the results of this work. Yusuf *et al.* (2018) also noted higher BAF in the shoot of *P. vittata* than in *P. calomelanos* when both were grown on Pd-contaminated soil. The highest BAF recorded for the two plants in this study were less than 1 and this disagrees with Zhao *et al.* (2002) who also reported *P. vittata* having a BAF greater than 10 in arsenic-contaminated soil for a relatively short time. The result showed that *P. vittata* has higher BAF and better potential to absorb and accumulate more Cd having recorded

higher values and no death throughout the experimental period. *P. ensiformis* recorded lower values for BAF and TF and died at higher concentrations. The TF measures the plant's capacity to transport toxic substances through the root to the developing shoot. Similarly, the process of phytoextraction often necessitates the transfer of heavy metals from contaminated soils through the root to the shoot. Comparing BAF and TF, inferences can be drawn about the capacity of various plants to take up toxic substances from the soil and translocate them to the shoots. Wei and Chen (2006) reported bioaccumulation factors ranging from 0.06 to 7.4 for *P. vittata* grown in a mining site which showed that soil properties played a significant role in arsenic and other heavy metals accumulation in ferns. Both *Pteris* species in this study had TF less than 1.0 showing that the two ferns did not effectively transfer Cd from their roots to the shoots which contradicts the report of Fayiga *et al.* (2005) who observed a TF value greater than one for *P. vittata*. The nature of their roots, their physiological responses to stress, and the makeup of the substrate could be a factor at play here.

CONCLUSION

P. vittata survived even at higher levels of Cd concentrations unlike *P. ensiformis* which died at higher concentrations. BAF and TF were higher in *P. vittata* than in *P. ensiformis*. Therefore, *P. vittata* had better phytoextraction potentials of cadmium than *P. ensiformis*.

CONFLICT OF INTEREST

Authors declare none.

AUTHORS' CONTRIBUTIONS

Oladele, O. T.: involved in the collection and identification of the plants, methodology and carried out the investigations, data collection, management, analysis, and writing (original draft). Bamigboye R. A.: co-supervised the experimental processes, involved in the collection and identification of the plants studied, in data management and literature review.

Oloyede, F. A.: supervised the experimental processes, designed the study, involved in the investigation, collection and identification of the plants used, methodology, data management and writing (review and editing).

Isa, M. O.: involved in data analysis, data validation, and manuscript review and editing.

Adenuga, A. A.: supplied the chemical used (cadmium [II] chloride), involved in design, methodology and data analysis.

Adejumo, M. A.: involved in data collection, analysis and validation, manuscript review and editing.

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