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Effects of Physicochemical Soil Properties on the Heavy Metal Concentrations of *Diplaziumesculentum* (medicinal plant) from the UKM and TasikChini, Malaysia

Hind S.Jasim[1,5]*, Mushrifah Idris[2], Aminah Abdullah[3] and Kadhum A.A.H.[4]

[1]School of Environmental and Natural Resource Sciences, UniversitiKebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[2]Tasik Chini Research Centre, UniversitiKebangsaanMalaysia, 43600 UKM Bangi, Selangor Malaysia
[3]School of Chemical Sciences and Food Technology, UniversitiKebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[4]Department of Chemical and Process Engineering, Universiti of Kebangsaan Malaysia, 43600 Bangi Selangor, Malaysia
[5]Department of Biology, ThiQar University,Nassiriya, Iraq.

*Corres.author : hind_sh87@yahoo.com

Abstract: Diplaziumesculentum is widely used as an edible plant and a medicinal plant in Malaysia and other regions worldwide. This study aimed to identify the soil properties (pH, EC, CEC,percentage clay content, and organic matter) that affect the heavy metal uptake in medicinal plant. The heavy metal concentrations (lead, iron, manganese, zinc, copper, and chromium) in the parts of D. esculentum (roots, rhizomes, young leaves, mature leaves, and fiddleheads) and soils where the plants grow were analyzed. The study was carried out in the UKM fern garden and TasikChini forest in Malaysia. The heavy metal concentrations were extracted using wet digestion method and determined by inductively coupled plasma spectroscopy ICP-MS. The heavy metals in the soil of TasikChini showed different values compared with those in the UKM fern garden. Correlation analysis showed that the properties of soil affected the concentrations of heavy metals in the soil and plant parts. Furthermore, many significant correlations were observed.
Key words: Physicochemical soil properties, Heavy metal soil, Heavy metal plant.

Introduction

In recent years, medicinal ferns play an important role in traditional medicine because of their increased potency in treatment of several diseases in humans. The human body requires numerous minor elements to reduce health risk factors [1]. A number of elements are important to plants; however, high concentrations of certain elements may cause harmful effects on plants and other organisms by consumption of affected plants [2]. Investigating the elemental composition of plants, especially medicinal plants, is significant because medicinal plants have therapeutic importance. In a plant–soil system, the strong absorption and fixation of heavy metals may cause over-absorption and residual accumulation of heavy metals in the soil [3,4]. Therefore, plants may be harmful to the health of humans [5]. Given this reason, investigating the heavy metal content of soil and plants is necessary [3].

Plants may transfer the heavy metals from soil to humans. Moreover, medicinal plants may be contaminated during growing and processing stages. The environment, pollution, atmosphere, and soil as well as harvesting and handling of plants are some of the factors that may lead to significant heavy metal contamination of medicinal plants [6]. The availability of these heavy metals for plant absorption depends on the physicochemical properties of soil, pH, electrical conductivity (EC), cation exchange capacity (CEC), percentage clay content, organic matter, and metal concentrations [2]. Plants readily assimilate elements through the roots, which dissolve in water and exist in ionic form [7]. High levels of toxic metals can also occur during medicinal preparations or processing when plants are used as active ingredients, as in the case of the presence of Pb and Hg in some Chinese, Mexican, and Indian medicines [8,9], or when plants are grown in polluted areas, such as near roadways or metal mining and smelting operations [10]. In addition, high levels of toxic metals may occur when agricultural expedients are used, including Cd-containing fertilizers, organic mercury, lead-based pesticides, and contaminated irrigation water [11].

Diplaziumesculentum (Woodsiaceae; Figure 1), known as *pucukpaku* in Malaysia, was selected to represent the wild medicinal fern in this study.*D. esculentum* is a fern species that is distributed in Malaysia and otherAsian countries, as well as in Australia and the Pacific Islands. This fern can reach an average height of 0.5 m to 2.5 m[12]. The leaves of *D. esculentum*are traditionally used as poultice to treat malaria, jaundice, constipation, earache, measles, and dermatitis. The extract of mature fronds is used as tonic after childbirth and to control fever. The rhizomes of this plant are used to cure hemoptysis and cough [13]. In this study, the heavy metals and their concentrations at the two different sites and the soils on which the plants grow were analyzed. This study aimed to identify the physicochemical properties of soil that affect heavy metal uptake by correlating the physicochemical properties of soil with the plant data.

FIGURE 1. Photo of*Diplaziumesculentu*

Materials and Methods

Sample Collection

The soil and plant samples in this study were randomly collected from UKM fern garden(Taman Paku Pakis, The National University of Malaysia, Bangi) and Tasikchini forest (southeast of the state of Pahang in Malaysia). Fern samples (three replicate) and corresponding soil (0-30 cm depth) were collected and stored in polyethylene plastic bags. The samples were transferred to the laboratory as early as possible. The soil samples were air dried in the laboratory before being ground and sieved to pass through 250 μm mesh size labeled and stored at 20°c to preclude the risk of hydrolysis and oxidation [14].

The samples of plant were directly washed gently with deionized distilled water for approximately 3minutes to remove soil particles adhered to the plants. Plant sample divided into root, rhizome, mature leaves, young leaves and fiddlehead. It was oven dried at temperature 40°c for 2 days and then finally crushed, labeled and stored until required for analysis.

Soil Physicochemical

The soil samples were sieved through a 0.63 μm stainless steel sieve. Soil PH, particle size, organic matter, cation exchangeable capacity (CEC) and electrical conductivity (EC) were determined to make accurate assessment of element reservoirs, mobility and bioavailability.

Soil pH was measured following Duddridge and Wainwright [15]. A 20 g dried soil sample was taken and added to 50 ml of deionized water and mixed for 30 minutes before pH value was taken. pH was measured using a DELTA 320 pH METER. The percentage of soil particle size was measured according to Badri and Aston [14], A10 g dried soil sample was sieved using a 63 μm sieve. The sieving process was done under slow flowing water. Organic matter content was determined by loss on ingnition technique. A 10 g of soil was transferred to silica crucible, that was previously weighed, the crucible with soil was dried at 105°C temperature until constant weight obtained, then the crucible was incinerated at a temperature 450 °C overnight the crucible was cooled and weighed. The procedure was repeated until a constant weight was observed.

Exchangeable cations (Ca^{2+}, K^+, Na^+ , and Mg^{2+}) were determined using the method of Jackson [16], 20 g air dried soil was transferred into a conical flask followed by an addition of 100 ml of an ammonium acetate (CH_3COONH_4). The mixture was shaken for 30 minutes and the extract was filtered into glass beakers. Aliquots of the filtrate was used to determine the Ca^{2+}, K^+, Na^+ , and Mg^{2+} using the inductively coupled plasma mass spectrometry ICP-MS. Determination (H^+, Al^+) method, 20g of air dried soil was taken into a conical flask 250 ml and add 100 ml of 1.0M KCL shake for 15 minutes. Funnel filter all the suspension to Whatman filter paper No.6 and collect filtrate,100 ml of the filtrate was transferred into 250 ml conical flask, 5 drops of indicator fenolftalien was added and titrated with 0.1N NAOH whirling and silent solution until the color turns pink on a regular basis. Total base used is equivalent to the total acidity. A point to make a solution of 0.1 N HCL extracted earlier colorless was added and then added 10 ml of 4.0 % NaF. The solution of 0.1N HCL was titrated until the pink color is gone. Second titration gives the Al exchange capacity. The number of H and Al exchange was calculated in meq/100g soil [17]. The citation exchange capacity was determined by summation of the acid and basic cation. The electric conductivity analysis was measured in the saturated extract [18].

Heavy Metals Analytical Procedure for Soil and Plant Sample

The dried plant material (the plant part of root, rhizome, mature leaves, young leaves, and fiddlehead) and soil samples were digested using the hot-block digestion procedure (USEPA Method 1993)[19] for total metal concentration. Sample weighting 1g were ground using digestion tube, 10ml concentrated HNO_3 (Merack Germany) was added to the digestion tube and covered with watch glass in the mouth of it. The mixture was left overnight and after that the digestion tube was placed into a block digester (ATM600 BLOCK,Australia) and heated at 95 ^oC for 1.5 hour then allowed to cool before it was added 7 ml H_2O_2 and continue to digest the sample for another 2 hour until the digest sample was clear .Additional HNO_3 not exceeding 5 ml was added to maintain a wet digest. The diluted equaregia (mixture of nitric acid and hydrochloric acid with a volume ratio of 1:3) was added to the dissolved digest residue and the solution was transferred into a 50 ml volumetric flask .de-ionized water was added to bring the volume of the solution up to 50 ml and the solution was filtered using 0.45 µm filter paper (Whatman,U.S.) to remove any particulates. Finally, the solution was analyzed using the inductively coupled plasma mass spectrometry ICP-MS.

Statistical analysis

Heavy metal contents of the plant were analyzed by one-way ANOVA based on Duncan test using a probability factor of $p<0.05$ and $p<0.01$by using software SPSS V.20.

Results and Discussion

The soil properties examined in the UKM fern garden and TasikChini forest are presented in Table (1). The soil pH was below 7 in both locations, indicating the acidic nature of the soil. Acidity is an important factor that regulates the mobility of metals in soil. The soil in Malaysia is generally acidic because it is highly weathered [20]. The organic matter in TasikChini forest was higher than that of the UKM fern garden. This finding is mainly because of the presence of many organic waste residues that contribute more organic matter after their decay. EC is a good indicator of plant growth. The EC levels observed in the UKM fern garden and TasikChini forest are slightly different. The CEC was higher in TasikChini forest than that in the UKM fern garden. Increasing CEC results in more rapid nutrient absorption and improvement of soil condition for crop growth.TasikChini forest has a clay type of soil, whereas the UKM fern garden has sandy soil.

Table 1: Physicochemical properties of the soil at different location

Sites	PH	EC dS/m	CEC	Organgmattar	Clay Content
UKM fern	4.51 -5.66	2.37-2.47	1.66-1.83	1.45-1.99	26.5-26.0
Mean n=3	5.23±0.63	2.41±0.05	1.78±0.10	1.59±0.35	27.06±0.2
TASIK	4.19-4.89	2.40-2.53	2.71-3.09	3.39-3.20	83-80
Mean n=3	4.64±0.39	2.45±0.07	2.89±0.19	3.43±0.25	80.45±0.35

The concentration of the selected heavy metals in various parts of *D. esculentum* and in the soil samples from the UKM fern garden and TasikChini forest are presented in Tables (2) and (3).

The heavy metal concentrations of Pb, Fe, Mn, Zn, Cu, and Cr in the soil from the UKM fern garden were 11.94, 1272, 65.78, 32.57, 64.91, and 20.04 mg/kg, respectively. The heavy metal concentrations of Pb, Fe, Mn, Zn, Cu, and Cr in the soil from TasikChini forest were 61.09, 2018, 613, 63.05, 159.10, and 14.20 mg/kg, respectively.

The results of this study showed that all of the metal concentrations were higher in the soil obtained from TasikChini forest than those from the UKM fern garden, except for the concentration of Cr. The total heavy metal concentrations in the soil at the two sites were lower than the critical concentrations of heavy metals in the soil potential toxicity [21], except for the Cu concentration in TasikChini forest, which was higher than the critical limit. The ranges of the critical concentrations of heavy metals are as follows: 100 mg/g to 400 mg/g Pb, 1500 mg/g to 3000 mg/g Mn, 70 mg/g to 400 mg/g Zn, 60 mg/g to 125 mg/g Cu, and 75 mg/g to 100 mg/g Cr.

Tables (2) and (3) show that Pb was highly accumulated in the plant roots from the UKM fern garden (3.26 mg/kg) and TasikChini forest (12.99 mg/kg). Pb had a lower value in the young leaves from the UKM fern garden (0.31 mg/kg) and TasikChini forest (0.24 mg/kg). Pb was present within the reference limit (10 mg/kg; Malaysian Herbal Monograph, 2009) [22]. The Pb concentration in the roots obtained from TasikChini forest exceeded the permissible concentration. Although Pb occurs naturally in all plants, it has not been shown to play any essential role in their metabolism.

Zinc is an essential element for plant nutrition. It serves as a component of a variety of enzymes, such as dehydrogenase, proteinases, peptidases, and phosphohydrolases.[23] indicated that the basic Zn functions in plants are related to the metabolisms of carbohydrates, proteins, phosphates, and auxins. The content of Zn in UKM fern garden was 38.58 mg/kg higher in the fiddlehead than those in other parts of the *D. esculentum* while Zn concentration in Tasikchini forest (98.85 mg/kg) was highest in the root of the *D. esculentum*. The concentrations of Zn in the roots, mature leaves, and fiddleheads from TasikChini forest exceeded the maximum permissible concentration based on the Malaysian Food Act (1983) and Malaysian Food Regulation (1985) was 40mg/kg [24] .

Manganese is an essential element in plant growth, but excessively high levels of Mn in soil can also hamper plant growth tremendously. Mn is required as a cofactor for a number of enzymes, particularly decarboxylase and dehydrogenase enzymes, which play an important role in respiratory carbon cycles [25]. The result, as shown in Table (2) and Table (3) that the high content of Mn in fiddlehead at UKM fern garden (22.48 mg/kg) and in root at Tasikchini (161.43 mg/kg).the permissible limit set by FAO/WHO (1984) was 2mg/kg [26]. After comparison of metal limit in the studied medicinal plant with FAO/WHO (1984), it was found that all parts of the plant accumulated Mn above this limit. Mn is required as a cofactor for a number of enzymes, particularly decarboxylase and dehydrogenase enzymes, which play an important role in respiratory carbon cycles [25].

The distribution of Copper within the parts of the plant is variable. Cu was highly accumulated in the fiddleheads (19.31 mg/kg) from the UKM fern garden and plant roots (49.13 mg/kg) from TasikChini forest. The Cu concentrations in the roots and fiddleheads from TasikChini forest exceeded the maximum permissible limit (30 mg/kg) as stated in the Malaysian Food Act (1983) and Malaysian Food Regulation (1985) [24] .

Chromium concentrations were highest in the roots of the plants from the UKM fern garden (3.03 mg/kg) and TasikChini forest (2.46 mg/kg). Cr was higher than the maximum allowed limit in food, which is 0.5 mg/kg (FAO/WHO, 2000) [27] .

The highest levels of heavy metals generally found in the roots of *D. esculentum*. This can be explained from three points. First, root hairs contain a higher surface area for adsorption and absorption of heavy metals when compared to leaves and roots. Thus, it is not surprising to note that the highest levels of heavy metal found in this plant organ. Second, root the first organ to take up all the heavy metals from the soil before distributing to other parts of the plant. It is not worthy that roots were found to have significantly higher levels of metals planted in polluted soils. Third, root is the only organ covered with soils when compared to leaves and fiddleheads. Therefore, its major function in the uptake of nutrients and pollutant is all manifest due to its physiological feature of this organ [28].

Table 2: Total heavy metals (mg.Kg^{-1}) measured in various parts of *D.esculentum*and soil from UKM fern garden

parts	Pb	Mn	Zn	Cu	Cr
Root	3.26±0.06	16.91±0.41	20.26±0.38	3.24±0.09	3.03±0.02
Rhizome	0.54±0.01	5.53±0.06	17.66±0.24	3.27±0.01	1.19±0.05
Young leaves	0.31±01	11.11±0.2	23.95±0.31	9.96±0.18	1.59±0.04
Mature leaves	0.86±0.02	7.91±0.16	13.84±0.10	2.87±0.03	2.61±0.03
Fiddlehead	1.73± 0.14	22.48±0.37	38.58±0.28	19.31±0.06	2.6±0.15
Soil	11.94±0.09	65.78±0.94	32.57±0.29	64.91±0.89	20.04±0.22

Table 3: Total heavy metals (mg.Kg^{-1}) measured in various parts of *D.esculentum*and soil from Tasikchini forest

Parts of plant	Pb	Mn	Zn	Cu	Cr
Root	12.99±0.07	161.43±1.13	98.85±0.81	49.13±0.27	2.46±0.05
Rhizome	1.88±0.02	29.97±0.17	38.82±0.14	7.93±0.10	1.09±0.11
Young leaves	0.24±0.01	15.77±0.53	27.81±0.36	15.15±0.38	0.9±0.04
Mature leaves	0.96±0.02	36.51±0.37	54.11±0.85	16.44±0.43	1.38±0.02
Fiddlehead	0.55±0.01	24.93±1.25	41.26±0.67	37.38±1.22	1.41±0.05
Soil	61.09±0.22	613.71±1.44	63.05±0.04	159.1±0.24	14.2±0.12

The significant correlation coefficient was applied to investigate the relationship between the heavy metals and physicochemical properties of the soil. Table (4) presents the significant correlation between the heavy metal concentration and soil properties observed in the UKM fern garden and TasikChini forest. The pH of the soil from the UKM fern garden was positively correlated with Pb concentrations ($r = 0.998$, $p < 0.05$). This finding indicates that Pb mobility increased with increasing pH of soil. EC was negatively correlated with Mn concentrations ($r = –0.999$, $p < 0.05$). This result infers that Mn concentrations decreased with increasing EC of the soil from the UKM fern garden and positively correlated with Zn concentrations ($r = 0.999$, $p < 0.05$) observed in the soil from TasikChini forest. Furthermore, CEC was positively correlated with Mn concentrations ($r = 1$, $p < 0.05$), and clay content was positively correlated with Cr concentrations ($r = 1$, $p < 0.05$). The other elements were not significantly correlated with any soil properties.

Table 4 :Correlation coefficient (r) between physicochemical soil properties with heavy metals concentrations in the soil at UKM fern garden and TasikChini forest

site	Soil properties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	pH	0.998*	0.94	-0.28	0.78	0.99
	Ec	-0.94	-.999*	0.63	-0.47	-0.96
	CEC	0.97	0.86	-0.11	0.87	0.96
	Organic matter	0.18	-0.13	0.87	0.79	0.11
	Clay content	-0.9	-0.99	0.7	-0.38	-0.93
Tasikchini forest	pH	0.52	0.18	-0.99	-0.93	-0.84
	Ec	-0.66	-0.36	.999*	0.98	0.73
	CEC	0.93	1.000*	-0.28	-0.5	0.4
	Organic matter	-0.82	-0.97	0.06	0.3	-0.59
	Clay content	0.04	0.39	0.76	0.57	1.000*

*. Correlation is significant at the 0.05 level (2-tailed).

The significant correlation between the heavy metal concentrations in the parts of *D. esculentum* from the UKM fern garden and TasikChini forest and physicochemical soil properties are presented in Tables (5) to (9). In Table (5), pH was negatively correlated with Pb concentrations in the root ($r = –0.999$, $p < 0.05$) observed in the UKM fern garden. CEC was positively correlated with Cr concentrations ($r = 1.00$, $p < 0.05$), and organic matter was negatively correlated with Mn and Zn concentrations ($r = −0.999$, $p < 0.05$) in the Tasikchini forest. Table (6) shows that the correlation between the CEC and the concentrations of Cu in the rhizomes of the plants was negative ($r = –0.999$, $p < 0.05$) in the soil of the UKM fern garden. While pH was negatively correlated with Cr concentrations (r = –0.999, p < 0.05) and positively correlated with Pb concentration (0.998, p<005) in the Tasikchini forest.

Table (7) shows that the pH was positively correlated with Mn concentrations (r = 0.999, p < 0.05). The EC was negatively correlated with Cu concentrations (r = –1, p < 0.05) and positively correlated with Pb concentrations (r = 1, p<0.01) in the young leaves of the plants from the UKM fern garden. The EC was negatively correlated with Zn (r = –0.998, p < 0.05) and Cu concentrations in the Tasikchini forest (r = –1,p < 0.05). Table (8) shows that the CEC of soil was positively correlated with Pb concentrations (r = 0.999,p < 0.05) and negatively correlated with Cu concentrations (r = –0.999, p < 0.05). The organic matter was negatively correlated with Mn concentrations (r = –0.999, p < 0.05) in the mature leaves of *D. esculentum* from the UKM fern garden. While the pH soil in the Tasikchini forest was positively correlated with Zn (r = 0.999, p < 0.05) and Cu (r = 1, p < 0.05) concentrations as shown in Table (8). In Table (9), the Zn concentrations in the fiddleheads of the plants were negatively correlated with pH (r = –0.997, p < 0.05). The Cu concentration in the fiddlehead of the plant was also negatively correlated with the organic matter (r = –1.00, p < 0.01) in UKM fern garden. The pH soil of Tasikchini forest was positively correlated with Pb (r = 0.998, p < 0.05) and Mn (r = 1.00, p < 0.01) concentrations. Additionally, the Cu concentrations were negatively correlated with the clay content (r = –0.999, p < 0.05).

The correlation analysis between the total heavy metal concentrations in the soils at two sites with heavy metal concentrations in the parts of the *D. esculentum* is shown in Table (10). The Pb concentrations in the soils collected from UKM fern garden was negatively correlated with Pb concentration in the root of the plant (-1.00,P<0.05) and Pb concentrations in the soils collected from Tasikchini forest was positvally correlated with Pb concentration in the young leaves of the plant (1.00,P<0.05) .

Table 5 :Correlation coefficient (r) between physicochemical soil properties with heavy metals concentrations in the root of the *D.esculentum* at UKM fern garden and Tasikchini

Site	Soil proprties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	PH	-.999*	-0.90	-0.94	-0.94	-0.6
	EC	0.93	0.66	0.74	0.73	0.87
	CEC	-0.98	-0.96	-0.99	-0.98	-0.46
	Organic matter	-0.19	-0.62	-0.54	-0.55	0.64
	Clay content	0.89	0.59	0.67	0.66	0.91
Tasikchini forest	PH	0.88	-0.03	-0.11	-0.89	0.18
	EC	-0.95	-0.15	-0.07	0.79	-0.35
	CEC	0.61	0.98	0.96	0.32	1.000*
	Organic matter	-0.43	-.999*	-.999*	-0.52	-0.97
	Clay content	-0.46	0.58	0.64	0.99	0.4

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6: Correlation coefficient (r) between physicochemical soil properties with heavy metals concentrations in the rhizom of the *D.esculentum* at UKM garden and TasikChini

Site	Soil proprties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	PH	0.8	0.12	-0.75	-0.99	-0.67
	EC	-0.5	-0.5	0.44	0.87	0.33
	CEC	0.89	-0.05	-0.85	-.999*	-0.79
	Organic matter	0.77	-0.94	-0.81	-0.34	-0.88
	Clay content	-0.41	-0.58	0.35	0.81	0.24
Tasikchini forest	PH	.998*	-0.97	-0.99	-0.77	-.999*
	EC	-0.97	0.92	0.95	0.87	0.99
	CEC	0.09	0.08	-0.02	-0.75	-0.19
	Organic matter	0.13	-0.3	-0.2	0.58	-0.03
	Clay content	-0.87	0.94	0.9	0.29	0.81

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7 :Correlation coefficient (r) between physicochemical soil properties with heavy metals concentrations in the young L.of the *D.esculentum* at UKM garden and Tasikchini

site	Soil proprties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	PH	-0.92	.999*	0.8	0.91	0.76
	EC	1**	-0.9	-0.97	-1.00*	-0.44
	CEC	-0.84	0.99	0.69	0.83	0.86
	Organic matter	0.17	0.27	-0.39	-0.19	0.81
	Clay content	0.99	-0.86	-0.99	-1.00	-0.36
Tasikchini forest	PH	0.55	0.95	0.97	0.98	0.92
	EC	-0.69	-0.99	-.998*	-1.00*	-0.98
	CEC	0.91	0.45	0.38	0.35	0.52
	Organic matter	-0.79	-0.24	-0.17	-0.14	-0.32
	Clay content	0	-0.62	-0.68	-0.7	-0.55

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8 :Correlation coefficient (r) between physicochemical soil properties with heavy metals concentrations in the mature L. of *the D.esculentum* at UKM garden and Tasikchini

Site	Soil proprties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	PH	0.99	-0.18	-0.68	-0.99	-0.51
	EC	-0.87	-0.22	0.91	0.87	0.13
	CEC	.999*	-0.34	-0.54	-.999*	-0.65
	Organic matter	0.34	-.999*	0.56	-0.34	-0.95
	Clay content	-0.81	-0.32	0.95	0.81	0.04
Tasikchini forest	PH	0.97	0.91	.999*	1.000*	0.95
	EC	-0.91	-0.97	-0.97	-0.98	-0.88
	CEC	-0.1	0.55	0.1	0.12	-0.15
	Organic matter	0.31	-0.36	0.12	0.09	0.36
	Clay content	-0.94	-0.53	-0.86	-0.85	-0.96

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 leve (2tailed).

Table 9: Correlation coefficient (r) between physicochemical soil properties with heavy metals in the fiddlehead of the *D.esculentum* at UKM ferngarden and Tasikchini

Site	Soil properties	Pb	Mn	Zn	Cu	Cr
UKM fern garden	PH	0.97	0.52	-.997*	-0.23	0.75
	EC	-0.79	-0.15	0.95	-0.17	-0.95
	CEC	1	0.66	-0.97	-0.39	0.63
	Organic matter	0.47	0.95	-0.15	-1.00**	-0.47
	Clay content	-0.73	-0.05	0.91	-0.26	-0.98
Tasikchini forest	PH	.998*	1.000**	0.83	0.86	0.96
	EC	-0.97	-0.98	-0.92	-0.75	-0.9
	CEC	0.09	0.16	0.67	-0.38	-0.12
	Organic matter	0.13	0.06	-0.5	0.57	0.34
	Clay content	-0.87	-0.83	-0.39	-.999*	-0.95

*. Correlation is significant at the 0.05 level (2tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10 :Correlation coefficient (r) between heavy metals concentrations in soil with heavy metals concentrations in the parts of the *D.esculentum*at UKM fern garden and Tasikchini

Correlation coefficient, r	UKM	Tasikchini
Pb in soil with Pb in root	-1.00*	0.87
Mn in soil with Mn in root	-0.70	0.98
Zn in soil with Mn in root	-0.06	-0.01
Cu in soil with Cu in root	-0.94	0.66
Cr in soil with Cr in root	-0.69	0.38
Pb in soil with Pb in mature. L	0.98	0.29
Mn in soil wihMn in mature.L	0.18	0.58
Zn in soil wih Zn in mature.L	0.89	-0.98
Cu in soil wih Cu in mature.L	-0.85	-0.92
Cr in soil wih Cr in mature.L	-0.40	-0.97
Pb in soil with Pb in young .L	-0.94	1.00*
Mn in soil with Mn in young .L	0.92	0.48
Zn in soil with Zn in young .L	-0.79	-0.99
Cu in soil with Cu in young .L	0.45	-0.99
Cr in soil with Cr in young .L	0.67	-0.57
Pb in soil with Pb in Rhizome	0.77	0.46
Mn in soil with Mn in Rhizome	0.46	0.05
Zn in soil with Zn in Rhizome	-0.42	0.97
Cu in soil with Cu in Rhizome	-0.85	0.95
Cr in soil with Cr in Rhizome	-0.58	0.82
Pb in soil with Pb in Fiddlehead	0.95	0.46
Mn in soil with Mn in Fiddlehead	0.19	0.19
Zn in soil with Zn in Fiddlehead	0.35	-0.90
Cu in soil with Cu in Fiddlehead	-0.79	-0.61
Cr in soil with Cr in Fiddlehead	0.83	-0.96

Conclusion

In this study, the physical and chemical soil properties (pH, EC, CEC, organic matter, and percentage clay content) are key factors in the mobility and accessibility of heavy metals in the soil and plants. The concentrations of heavy metals (Pb, Zn, Cr, Mn and Cu) in soil from the UKM fern garden and TasikChini forest had different levels, depending on soil type. The concentrations of heavy metals in the soil and medicinal plants were below the critical limit. The roots of *D. esculentum* more likely absorbed heavy metals than the other parts of the plants. Correlation analysis showed that the soil properties could affect the heavy metal concentration in the soil and plant parts. Moreover, the heavy metal content in the soil was correlated with the heavy metal content in the plants, but variation occurred, depending on the soil properties. Thus, the heavy metal distribution in the soil and plant samples should be monitored to help prevent environmental pollutions in terms of soil quality and ensure safe use of medicinal plants.

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