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Content of Heavy Metals in Plant and Soil Collected from Urban and Remote Natural Habitats

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Abstract: The aim of this study was to determine the level of heavy metals in the plant parts (leaves and fruits) and in the soil of two species of *Ficus (F.fistulosa*and*F.hispida)*. The samples were collected from four locations (Bangi, Ayer Hitam, Chini and Bera Forest Reserves) inMalaysia.Heavy metals (Pb, Fe, Mn and Zn) were detected using an inductively coupled plasma mass spectrometer (ICP-MS). In general, the concentrations of heavy metals in the soil and plant parts were detected.*Ficusfistulosa*showed higher heavy metals concentration of Pb, Zn and Mn at 0.65, 121.15 and 10.75 mg /kg DW of leaves than *F.hispida.* The results showed that leaves samples had significantly ($P<0.05$) higher heavy metals compared to fruits in both *Ficus* species.A high amount of soil Fe were found in urban area Bangi and Ayer Hitamat 3135.42 and 2774.63 mg/kg of leaves. Results showed growing locations effect of the physicochemical properties (pH, organic matter and percentage grain size) in the soil. However, growing locations play an important role in the heavy metals content of *Ficus*leaves and fruits.The results indicated that the *Ficus* fruits of urban area had the highest heavy metals content whileremote area had the lowest for both *Ficus*species.

Key words: *Ficus* · *Fistulosa* · *Hispida* · Heavy metals · Urban and remote areas

INTRODUCTION

*Ficus*L., commonly known as Fig, is considered as a keystone species in tropical rain forests as it plays very fundamental role in ecosystem, due to its fruits which are eaten by insects, birds and animals throughout the year. The genus *Ficus* represents an important group of trees, not only for their immense value but also for their growth habits and religious value. The genus *Ficus*(Moraceae) comprises about 1200 species distributed mainly in tropical and subtropical regions [2]. *Ficus*, is a shrub or small tree, found throughout the year, growing in evergreen forest, moist localities, banks of stream, deciduous forests, to an elevation of 1800 m above sea level, often cultivated in villages for shade and its edible fruits in India, Sri Lanka, Myanmar, southern region of the Republic of China, New Guinea, Australia and Andaman island. Almost all parts of this plant used are bark, leaves, roots, fruits and latex. This genus is characterized by its constituents of coumarins, phytosterols, triterpenes, flavonoids as well as alkaloids and tannins [2,3]. One of the most dangerous ecological crises being faced by all living organisms at present is the environmental pollution. Environment pollution is the presence of a pollutant in the environment; air, water and soil, which may be poisonous or toxic and will cause harm to the living organisms. In the environment, different types of pollutants cause objectionable effects, reducing the quality of life and may eventually cause death [4]. Certain chemical pollutants are capable of remaining in the environment for a significant period of time and accumulate at levels that may be harmful to humans. Among chemical pollutants, heavy metals have been considered in the main category, which is toxic or poisonous even at low concentration [5]. Their effects are highly varied depending on the species sensitivity, the intensity and duration of the exposure. The term “heavy metals” is a general collective term, which applies to the groups of metals and metalloids with

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atomic density greater than 4 g/cm^3 or 5 times or more, greater than water such as lead (Pb), cadmium (Cd), zinc (Zn), mercury (Hg), arsenic (As), silver (Ag) chromium (Cr), copper (Cu) iron (Fe) and the platinum group elements [6,7]. From the point of view of environmental pollution, heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for the proper functioning of biological systems, whereas other elements such as Pb, Hg and Cd have no essential functions in plants and cause toxicity even at low concentration [8]. Heavy metals are released to the environment from natural weathering processes or industrial activities such as the application of insecticides and municipal sewage and sludge [9]. Mobility and transportation of heavy metals are strongly influenced by its adsorption and desorption in the soil. However, the capacity of soil to bind heavy metals depends on the amount and nature of the binding sites in soil which is influenced by many factors such as the soil pH, organic matter content and soil type [10]. The objective of this study to determine the concentration of heavy metals in soil and the various parts of*Ficus* (leaves and fruits).

MATERIALS AND METHODS

Study Areas: The leaves and fruits of *F. hispida*and *F. fistulosa* and soil sampleswere obtained from fourareas (Chini FR, Bera FR, Ayer Hitam FR and Bangi FR) Malaysia.

Preparations of Plant and Soil Samples: The *Ficus*samples were washed with tap water to remove soil particlesfollowed by three times of washing, twice with distilled water and once with distilled deionized water. Samples were then dried with tissue paper and separated to leaves and fruits and cut into small pieces. Finally, samples were oven dried at 60ºC for two days until they reach a constant weight [11]. Collected soil samples were air-dried in the laboratory before being ground and sieved using a 250µm mash [12].

Plant and Soil Digestion: Extraction of heavy metals from theplant and soil, were performed by wet digestion according to the AOAC methods [11]. Dried samples were weighed in a conical flask with HNO_3: $HclO_4$ (2:1) for 3-4 hours on a sand bath at a temperature of 100°C until all brown fumes had changed to white. Ten ml of HCl was added to the sample to digest the inorganic and oxide salts. Digested samples were filtered with a 0.45 µm pore size cellulose nitrate membrane filter paper, "Millipore" and the volume was made up to 50 ml with deionized water. Heavy metals concentrations were determined by the Inductive Coupled Plasma Mass Spectrometer ICP-MS. (ELAN 9000, Perkin Elemer SCIEX).

Physicochemical Properties of the Soil: Soil samples were sieved through a <63 ìm stainless steel sieve. Soil pH, particle size, organic matter wasdetermined. Soil pH was determined according to methods previously described by Duddridge and Wainright [13]. A 20 g of dried soil sample was weightedin a 50 ml of deionized water were added and mixed for 30 min; pH was then measured using a DELTA 320 pH meter. The percentage of soil particle size was determined according to Badri and Aston [14]. A 10 g of dried soil sample was passed through a 63 ìm sieve with gradually flowing water. Organic matter content was determined using the loss-on-ignition technique [15].

Statistical Analysis: All the analyses were conducted in triplicates for each location. The heavy metals values were evaluated with the two-way ANOVA and Duncan's triplicates Range Test using SPSS software (SPSS ver.19). Significant differences ($P<0.05$) among the locations (urban and remote area) and *Ficus* species were analyzed by Duncan 'triplicates range test Bryman and Cramer [16].

RESULTS AND DISCUSSION

The Pb Content of *Ficus* Leaves and Fruits: Contents of Pb (expressed as mg/kg DW) for *Ficus*species *F.fistulosa* and *F.hispida*are presented in Table 1. For leaves and fruits the maximum Pb were obtained for *Ficusfistulosa* species in Chini FR when compared to *F.hispida*. Among within species, leaves showed the higher (Pb) then fruit. Table 1 showed significant difference ($p<0.05$) in the Pb content of *Ficusfistulosa* between leaves and fruits. *Ficusfistulosa* leave and fruits for Bangi FR gave the highest Pb content (0.65and 0.27 mg/kg DW) when compared with *F.hispida* leaves and fruitsBangi FR (0.58 and 0.21 mg/kg DW). The Pb content in different growing environment (TasikChini, TasikBera, Ayer Hitam and Bangi FR) of *Ficus*leaves and fruits is shown in Table 1 with higher Pb in urban area. High content of Pb (0.65 mg/kg DW) were obtained from *F.fistulosa*leaves in Bangi FR. After Bangi FR region, leaves of *F.fistulosa*Ayer HitamFR(0.61 mg/kg DW) had high content of Pb in extract. In both area (remote and urban), the total Pb

Table 1: The Pbcontent of *Ficus*leaves and fruits extracts, (mg /kg DW)from four sampling locations.

	F. fistulosa		*F. hispida*	
Location	Leaves	Fruits	Leaves	Fruits
Bangi FR	0.65±0.04^{Aa}	0.27±0.05^{Ca}	0.58±0.02^{Ba}	0.21±0.02^{Da}
Chini FR	0.50±0.06^{Ab}	0.17±0.03^{Cb}	0.42±0.01^{Bc}	0.15±0.01^{Cc}
Ayer Hitam FR	0.61±0.02^{Aa}	0.25±0.07^{Ca}	0.51±0.02^{Bb}	0.18±0.02^{Db}
Bera FR	0.53±0.04^{Ab}	0.12±0.06^{Cb}	0.30±0.01^{Bd}	0.14±0.01^{Cc}

$^{A-E}$ Different letters within the same row indicate significant differences (p<0.05).

$^{a-e}$Different letters within the same column indicate significant differences (p<0.05).

Table 2: Fe content of *Ficus*leaves and fruits extracts, (mg /kg DW) from four sampling locations.

	F. fistulosa		*F. hispida*	
Location	Leaves	Fruits	Leaves	Fruits
Bangi FR	166.54±5.80^{Ba}	28.85±2.34^{Da}	244.71±7.58^{Aa}	69.38±3.58^{Ca}
Chini FR	136.50±6.42^{Bc}	21.98±1.16^{Dc}	219.77±4.70^{Ac}	55.17±2.70^{Cc}
Ayer Hitam FR	143.92±3.52^{Ba}	27.36±1.21^{Da}	226.50±2.39^{Ab}	64.78±1.39^{Cb}
Bera FR	127.14±2.60^{Bd}	24.10±1.12^{Db}	205.02±3.98^{Ad}	52.27±1.98^{Cd}

$^{A-D}$ Different letters within the same row indicate significant differences (P<0.05).

$^{a-d}$ Different letters within the same column indicate significant differences (P<0.05).

content in the urban areas(Ayer Hitam FR and Bangi FR) were more than the remote areas (Chini FR and Bera FR). One possible reason for the increased Pb content with the urban areas might be due to the increase in organic matter, rain rate and topography of the land. Pb values for the Ficus leaves and fruit in this study were lower than that of Dayang and Che Fauziah [17] for different medicinal plants.The Pb content in this study showed that leaves and fruits were lower than that of Kamaruzzaman *et al*. [18].

The Fe Content of *Ficus* Leaves and Fruits: Table 2 shows Fe values for *F.fistulosa*and *F.hispida* leaves and fruits. Withinspecies leaves showed the higher Fe content than fruit respectively. The fruits from *fistulosa*variety contained the lowest Fe content as compared to allother samples. The following order was observed: *F.hispida* leaves>*F.fistulosa* leaves >*F.hispida*fruits>*F.fistulosa* fruits. The result ranged from 244.71 to127.14 mg/kg DW in leaves and 69.38 to 21.98 mg/kg DW in fruits. Significant differences (p<0.05) in Fecontent were found among the four growing locations. Both Bangi FR and Ayer Hitam FR areashad higher Fe content. The Fe content obtained from*F. hispida*leaves was higher significantly (p<0.05) than the extract obtained from *F. fistulosa*leaves. However, for Fe values sample extracted of *Ficushispida* leaves and fruits from urban areasBangi FR and Ayer Hitam FR were significantly (p<0.05) different from remote areas (Chini FR and Bera FR) also both were significantly (p<0.05) Chini FR and Bera FR for both (leaves and fruits) of *Ficushispida*. When comparing the results from this study with other study, values from different sources seriously differ. The Fe mean value in this study showed that leaves and fruits were higher than that of Khairiah *et al*. [19].

The MnContent of *Ficus* Leaves and Fruits: Table 3 shows Mn content for two different species of *Ficus* leaves and fruits from four different growing environment(Chini FR, Bera FR, Ayer Hitam FR and Bangi FR). The results showed that *F. fistulosa*leaves and fruitsare having significantly (p<0.05) higher Mn content compared to *hispida* leaves and fruits. The results ranged from 121.15 mg/kg DW in *F. fistulosa* leaves to 21.50 mg/kg DW in *F. hispida*fruits. Significant differences (p<0.05) in among the different leaves, fruit species and also among the same fruit species at different locations (Bangi FR, Chini FR, Ayer Hitam FR and Bera FR). *F. fistulosa* leaves for Chini FRshowed higher Mn content compared to*F. hispida*species. Among each species leaves showed the higherMn contentthan fruit. The following order was observed: Chini FR>Bera FR>Ayer Hitam FR >Bangi FR. The Mnvalues for the guava seed, skin, pulp old leaf and young leaf ranged from 0.01 to 0.14 mg /kg in this study were higher than that of Khairiah *et al*. [19] for different plant varieties and location.

Table 3: Mn content of *Ficus*leaves and fruits extracts, (mg /kg DW)from four sampling locations.

	F. fistulosa		*F. hispida*	
Location	Leaves	Fruits	Leaves	Fruits
Bangi FR	106.94±1.57^{Ad}	32.21±0.51^{Cd}	66.72±0.54^{Bd}	20.18±0.83^{Dc}
Chini FR	121.15±2.55^{Aa}	44.51±0.50^{Ca}	78.46±1.82^{Ba}	24.10±0.50^{Da}
AyerHitam FR	110.71±3.61^{Ac}	36.20±0.90^{Cc}	71.24±2.65^{Bc}	21.50±0.13^{Dc}
Bera FR	116.37±3.86^{Ab}	39.62±0.72^{Cb}	76.26±1.21^{Bb}	22.96±0.19^{Db}

$^{A-D}$ Different letters within the same row indicate significant differences (P<0.05).

$^{a-d}$ Different letters within the same column indicate significant differences (P<0.05).

Table 4: Zn content of *Ficus*leaves and fruits extracts, (mg /kg DW)from four sampling locations.

	F. fistulosa		*F. hispida*	
Location	Leaves	Fruits	Leaves	Fruits
Bangi FR	10.75±0.20^{Aa}	3.15±0.26^{Ca}	5.78±0.96^{Ba}	1.22±0.12^{Da}
Chini FR	9.26±0.35^{Ab}	2.58±0.22^{Cb}	4.67±0.57^{Bb}	1.07±0.10^{Db}
AyerHitam FR	7.69±0.27^{Ad}	3.07±0.18^{Ca}	5.34±0.50^{Ba}	1.25±0.07^{Da}
Bera FR	8.65±0.23^{Ac}	2.70±0.03^{Cb}	4.08±0.11^{Bb}	1.35±0.21^{Da}

$^{A-D}$ Different letters within the same row indicate significant differences (P<0.05).

$^{a-d}$ Different letters within the same column indicate significant differences (P<0.05)

The ZnContent of *Ficus*Leaves and Fruits: The effects of speciesand growing location(remote and urban areas) in Zn contentis shown in Table 4. Significant differences (p<0.05) in Zn content in leaves and fruits of *F.fistulosa* and*F.hispida*were found among the different growing environment. *Ficusfistulosa*leaves gave the highest Zn content (10.75 mg/kg DW) in urban area Bangi FR when compared with remote area Bera FR (8.65 mg/kg DW). The results showed that *F.fistulosa* leaves and fruits were had significantly (p<0.05) higher Zncompared to *F.hispida.* Zn content in leaves in both species was higher than fruits. These results indicated that for both species, part of plants and growing location had effect on Zn content.Comparing Zn content from this study and other published data is difficult due to the fact that content of Zn can be influenced by extracting solvent, cultivar and location.Dayang and CheFauziah [17] reported that Zn of 24 medicinal plants samples and Zn values ranged from 17.70 to 87.55 mg/kg.

Pb Content in the Soil: Among the soils studied, the Pb content in the four study areas were different (Fig. 1). The highest Pb content was found in Bangi FR soil 6.78 mg/Kg and the lowest Pb concentration was in the Chini FR soil 2.16 mg/kg. The reason may be due to the high and low concentration of lead probably depended mainly on the basic existing rock material in those particular areas. According to [20] sedimentary rock areas, shale and mudstone have an average Pb content of 23 mg/kg.

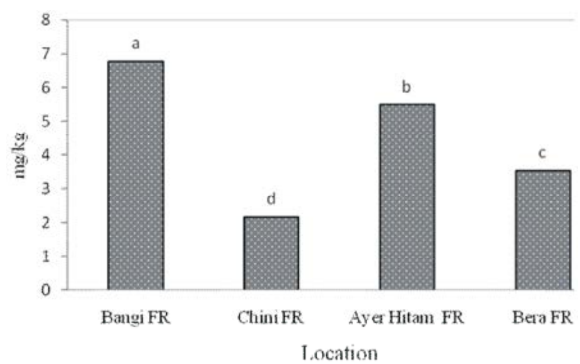

Fig. 1: Pb concentration in the four soils of the study areas.
$^{a-d}$Mean with different letters are significantly different (P< 0.05)

These results are different to that detected in the FELDA Chini soil as this area consists of basic sedimentary rocks. According to Khairiah *et al*. [19] the average Pb content 0.12- 35 mg/kg.The average in FELDA Chini was only slightly higher than the value recorded. The highest amounts of Pb detected in the Bangi FR meant that Pb had a high tendency to be present in soils with high organic content.

Fe Content in the Soil: Among the metals studied, Fe was the metal found in the highest concentration at the four sites studied (Fig. 2). The Fe content was highest in Bangi FR soil in the order of Bangi

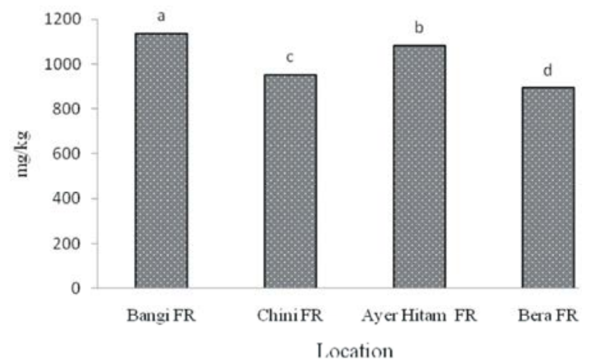

Fig. 2: Fe concentration in the four soils of the study areas.
[a-d]Mean with different letters are significantly different (P< 0.05)

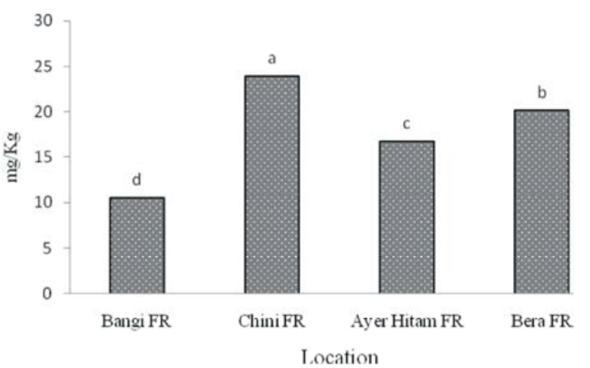

Fig. 3: Mn concentration in the four soils of the study areas.
[a-d]Mean with different letters are significantly different (P< 0.05)

FR>Ayer Hitam>Chini FR>Bera FR soil at 1135.46, 1081.57, 952.94 and 892.51 mg/kg respectively. The presence of Fe in high concentrations associated with the remote areas compared with urban areas. Turekian and Wedepohl [21] in their study mentioned that areas consisting of sedimentary rocks normally possess high amount of Fe approximately 47,200 mg/kg. Fe existed in high concentration at all the study sites in the Bangi and Ayer Hitam areas especially in the soil from urban areas. This implied that Fe has the tendency to form a complex with organic materials in the soil, as these areas contained quite a high percentage of organic matter and low pH. According to [22], organic soil at pH 3 has a high amount Fe and this metal exists in a strong complex form with organic matter. But at high pH, Fe would be released as the available form into the soil thus increasing its availability to plants uptake. Relatively high content of Fe in the remote areas could be due to the high tendency of the Fe to combine with organic matter at low soil pH thus increasing the available form of Fe in the soil. The result suggests that Fe availability for plant uptake in Chini FR and Bera FR was relatively high compared to that in the other sites. The organic rich soils in Bangi FR have a great potential to retain heavy metals as shown in this study.

Mn Content in the Soil: Among the sites studied, the soils of Chini FR showed the highest Mn concentration 23.89 mg /kg (Fig 3). Mn in the remote areas was found to be the highest, with the order being Chini FR>Bera FR>Ayer Hitam FR>Bangi FR 23.89, 20.11, 16.72 and 10.50 mg/kg respectively. The types of parent material of this soil could have been the source of the predominantly high amount of Mn. According to Turekian and Wedepohl [21] granite and sedimentary rocks normally contain quite high concentrations of Mn in the parent material for both types of rock. Besides the Chini RF soil, total Mn concentration was also high in the Bera FR soil compared with Bangi FR and Ayer Hitam FR soil. The Chini FR soil has more than 70% of Mn content in Bangi FR soil, indicating the high Mn content increased with the organic matter in soil. This could occur because the basic rock materials in Bangi was sediment. The high Mn content in the Chini FR indicated the high availability of Mn for plant uptake in the study area.

Zn Content in the Soil: The soil from Chini FR showed the highest concentration of Zn (8.21 mg/kg) (Fig. 2) and the levels was higher than the average of the Zn content in Bera FR, Ayer Hitam and Bangi FR. The Zn content in Bera FR, Ayer Hitam and Bangi FR soils are 6.06, 5.48 and 3.40 mg/kg respectively. From this study, Zn was seen to be highest in the remote areas. This indicated that Zn was originally quite high in the basic rock material and formed a complex form with the organic materials. For the remote area the amount was also quite high, different to that found at urban areas Bangi FR and Ayer Hitam FR soils (Fig 2). The Zn content was generally low in all soil sites besides having low concentrations in the basic rock material. A relatively high concentration of Zn in the soil indicates the availability and high uptake of Zn by the plant (Table 4). Comparing Zn content from this study and other published data is difficult due to the fact that content of Zn can be influenced by extracting solvent, depth and location. Khairiah *et al*. [19] reported that the Zn values for three different locations were reported between 0.38 to 3.40 mg/kg.

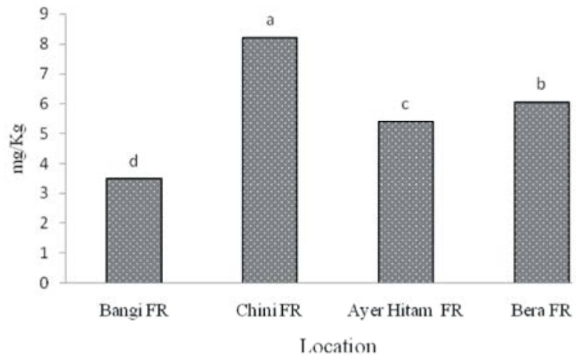

Fig. 4: Zn concentration in the four soils of the study areas.
[a-d]Mean with different letters are significantly different (P< 0.05)

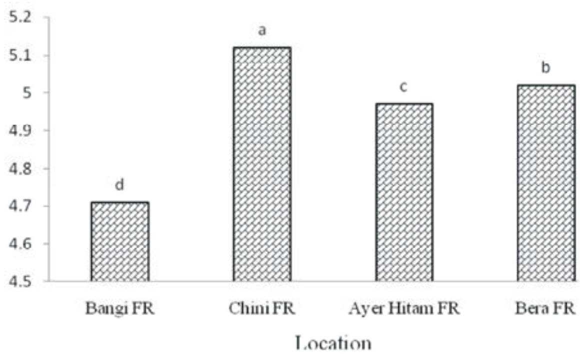

Fig. 5: Effect of location on pH of the study areas
[a-d]Mean with different letters are significantly different (P< 0.05)

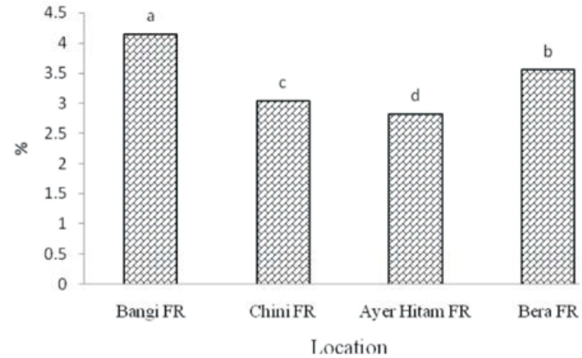

Fig. 6: Effect of location on organic content of the study areas
[a-d]Mean with different letters are significantly different (P< 0.05)

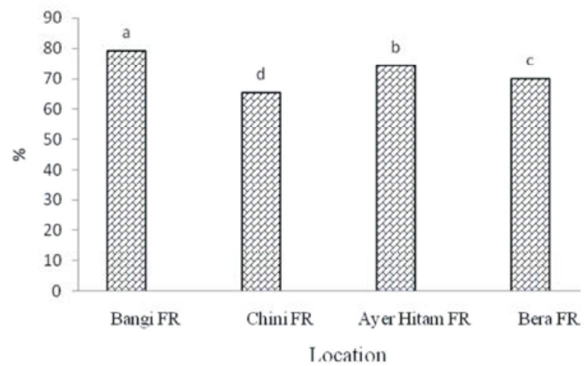

Fig. 7: Effect of location on percentage grain size of the study areas
[a-d]Mean with different letters are significantly different (P< 0.05)

Physicochemical Properties of Soil: The average percentage of organic matter, grain size (<63 um) and pH of the soil from the study sites were as followin Fig 5, Fig 6 and Fig 7. Bangi FR had pH 4.71,4.14% organic content and grain size 79.15%. Chini FR had pH 5.12, 3.04% organic content and grain size 65.41%, Ayer Hitam FR had pH 4.97, 2.82% organic content and grain size 74.28% and Bera FR had pH 5.02, 3.56% organic content and grain size 70.02%. The highest percentage organic content was found in the soil from Bangi FR followed by that from Bera FR,Chini FR andAyer HitamFR. As for the grain size the soils from Bangi FR and Ayer Hitam FR had higher percentage compared to the other sites (Fig. 7). Bangi FR and Ayer Hitam FR soils were both more acidic than Chini and Bera FR. The data showed that areas with high percentage of organic matter have low pH values and this was due to the decomposition of humus or litter in the topsoil. While grain size in Chini FR, Bera FR and Ayer Hitam were reasonably high probably due to sandy soil from these sites.

CONCLUSION

The current study investigated the effects of species and growing location on heavy metals (Pb, Fe, Mn and Zn) of *Ficus* (leaves and fruits) and soil. The results showed that the urban areas (Bangi FR and Ayer Hitam FR) havehigher contentof heavy metals in plant (Pb, Fe and Zn) and soil (Pb and Fe)than the remote areas.The heavy metals (Pb, Fe, Mn and Zn) of *Ficus* leaves and fruits extracts were significantly different by location.*Ficusfistulosa*used in this study had contained the highest level of heavy metals. The high amounts of soil Fe and Mn in the soils of the study area.

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