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TRACE ELEMENTS DISTRIBUTION IN HEIRLOOM PADDY PANDASAN CULTIVATED UNDER FIELD CONDITIONS OF DRY AND WET SOIL

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ABSTRACT

Trace elements phytoavailability depends on the physical and chemical properties of soil. At the Crocker range of West Coast Sabah, Malaysia, the *Pandasan* paddy variety can be cultivated as flooded rice paddies or upland rice on acidic soil. *Pandasan* paddy samples were collected in Kiulu subdistrict from traditional farmer at two different locations. Available sources of trace elements were from weathering, fertilizers and pesticides. Soil and plant samples were collected after two months of seed sowing and during harvest season which was five months old for heavy metal analysis by inductively coupled plasma optical emission spectrometry (ICP-OES). Translocation factor of arsenic from root to grain indicated this trace element was very mobile in *Pandasan* paddy cultivated at dry soil compared to wet soil followed by zinc. Although, cadmium was not detected in paddy cultivated at flooded field for both, soil and plant, cadmium was detected in soil and plant roots cultivated in dry condition. Enrichment factor results suggested that *Pandasan* plant cultivated on dry soil was only a good bioindicator for lead and zinc. *Pandasan* grain was rich with iron followed by zinc. Selected heavy metals accumulation in *Pandasan* grain cultivated in flooded field did not exceeded the permissible limit of Malaysia Food Regulation 1985. However arsenic and plumbum concentration in *Pandasan* grain harvested from dry soil exceeded the permissible limit of Malaysia Food Regulation 1985. Health risk of heavy metals toxicity can be reduced if *Pandasan* paddy is cultivated in flooded field compared to dry soil.

Keywords: *Phytoavailability, food safety, heavy metal, upland paddy, Borneo.*

INTRODUCTION

In rural agricultural land where industrial area is non-existent, heavy metal contamination can still occur through human activities such as usage of pesticides and fertilizers (Mohammed & Makame, 2015). Since the green revolution, farmers relied on man-made pesticides and fertilizers to increase plant yield. However, in long term without sustainability practices and lack of education among rural farmers, their land productivity had declined (Mohamed *et al.*, 2016). Accumulation of high concentration of heavy metal in soil will caused phytotoxicity in plants (Alfaraas *et al.*, 2016). Subsequently threaten human health through consumption of food grown in land that contain high concentration of trace elements (Ihedioha *et al.*, 2016). Heavy metals are non-biodegradable and will continue to accumulate in agriculture soil if not decontaminated. Phytoremediation is a promising environment friendly technology using living plants to remediate contaminated soil such as heavy metals. Phytoremediation is a low cost soil remediation technique which is affordable for rural farmers to practise with the condition an easy to cultivate native plant is available as heavy metal accumulator. Rice with its high biomass is a good heavy metal accumulator and can be grown in acidic soil (Takahashi *et al.*, 2016). Heavy metal bioavailability is more readily in acidic soil. Many studies have shown that different rice species and different cultivators within different species have different characteristic ability to uptake heavy metals (Bhattacharya 2017, Duan *et al.*, 2017). However, limited data is available on indigenous paddy grown in agricultural land in Malaysia to access which cultivator or genotype is a good candidate in heavy metal soil remediation (Abdul Aziz *et al.*, 2015).

Agriculture is the main sector providing livelihood to the indigenous people living in the Crocker range. Although farmers do not only plant rice to supplement their household income, rice is the staple food (Hanafi *et al.*, 2009). Every year the diverse ethnic groups of Sabah state celebrate harvest festival and rice play an important role in cultural ceremonies. The *Pandasan* paddy variety is a traditional cultivator and not grown as commercialize paddy like the *Siam* paddy variety. As time passed and number of traditional paddy farmers decreased, *Pandasan* paddy will be less cultivated in the future as food resource. In favor of biodiversity conservation initiatives, Translocation Factor (TF) and Enrichment Factor (EF) of selected heavy metals distribution in different parts of *Pandasan* plant were analyzed to evaluate whether there are other prospect for *Pandasan* paddy not only as food source but other functions. The *Pandasan* variety is very well adapted with the climate and terrain features of the Crocker Range where it can be grown on wet and dry soil. Therefore, trace element uptake characteristic of *Pandasan* paddy from both growing conditions on wet and dry soil were assessed to identify whether *Pandasan* paddy variety can be a good specific heavy metal accumulator in ensuring sustainable agriculture in Crocker range.

MATERIAL AND METHODS

Soil and paddy plants samples were collected from sub-district of Kiulu which is located within the Crocker Range of West Coast Sabah (Malaysia) at two different villages from the same traditional paddy farmer. A minimum of random five clumps of whole paddy plants were uprooted together with soil were obtained from each location where paddy cultivated from flood plain were from the village of Kampung Poturidong Lama (6˚3' 2" N, 116˚17' 43" E), and paddy cultivated on hilly slopes depended only on rain as water resource were from Kampung Mantaranau

(6˚3' 0" N, 116˚25' 58" E). Paddy plants were harvested two times during paddy life cycle which at growing phase two months old (October 2016) and when rice grain had matured about five months old (January 2017). The indigenous paddy plant variety that were collected for this study is known as '*Pandasan*' (Accession Number IRGC 13091) by the local people which might be named according to the original location where the cultivator were grown in Pandasan area in Kota Belud district within the Crocker Range as well.

Soil collected near roots of paddy plant were air-dried. Dried soil samples were grinded with mortar and pestle. Then soil were sieved through 63μm size mesh before 1 gram of each homogenized soil samples were fully digested with aqua regia solution HNO_3:HCl (1:3) heated at 70˚C. Paddy plants were separated into three parts of roots, leaves and grains which were dried at 60˚C in oven and later ground into a fine powder. Homogenized plant samples of 1 gram were digested with 20ml HNO_3 for overnight. Then samples were heated at 120˚C in the oven for four hours. Samples were filtered with 0.45μm pore size membrane filter paper and diluted when cooled. The content of trace elements in soil and paddy plants were determined by ICP-OES (Perkin Elmer Optima 5300DV).

RESULTS AND DISCUSSION

Borneo Island is one of the oldest rainforest in the world created after exposed parent materials had formed soil as the ultimate product of continuous weathering. Soil is a medium which provide nutrients for plants to grow and produce food for consumers as they are producers in the food web chain. According to United States Department of Agriculture (USDA) soil taxonomy, a big part of terrestrial area in Borneo Island can be generally categorized as "ultisols". Characteristic of ultisols soil can be seen in the northern portion of the island of Borneo, where the Crocker range is located with visible soil profile sections of red clay soils on agricultural land which is typically acidic (Soehady Erfen *et al.*, 2016). Acidic soil can naturally increase the mobility and phytoavailability of heavy metals in soil (Abdul Aziz *et al.*, 2015). Zinc in Crocker Formation clay soil have high mobility followed by Cu, Ni, Cr, and Pb (Musta *et al.*, 2003). In the same manner, Zn availability at both wet and dry soils of this study indicates Zn mobility was also higher compared to other detected trace elements except for Fe (Table 1). Fe is more bioavailable in Malaysia agriculture areas compared to Zn (Abdul Aziz *et al.*, 2015, Khairiah *et al.*, 2013, Hanafi *et al.*, 2009). Moreover red soil is rich with iron oxides (Khairiah *et al.*, 2012). Although Fe is more bioavailable in soil compared to other trace elements, Fe appeared to be more bounded in the plant roots compared to the other parts of the *Pandasan* paddy plant (Figure 1). Zn translocation efficiency in *Pandasan* plant from root to other upper part of *Pandasan* plant is higher than Fe (Figure 2). Pandasan grain is rich in with iron and zinc notably when cultivated at dry soil (Table 1). Nevertheless, translocation of arsenic from root to grain is more efficient compared to zinc when *Pandasan* paddy were cultivated at dry soil (Figure 2).

Table 3. Mean concentration of trace elements in soil collected at different point of paddy life phase and in grain with comparison of statutory limit in food product (mg/kg) according to Malaysia Food Regulation 1985 (MFR 1985).

	Wetland			Dryland			MFR 1985
	Soil	Soil	Brown Rice	Soil	Soil	Brown Rice	
	2 months	5 months		2 months	5 months		
As	n.d.	0.34±0.00	0.12±0.00	0.24±0.09	4.38±0.06	3.38±0.6	1
Cd	n.d.	n.d.	n.d.	0.15±0.01	0.85±0.03	n.d.	1
Cr	1.03±0.00	2.75±0.03	0.11±0.00	1.16±0.01	5.87±0.09	2.10±0.03	N.A.
Cu	0.64±0.00	0.93±0.01	0.05±0.00	1.72±0.01	1.47±0.01	0.71±0.05	30
Fe	2224.09±0.62	1719.03±16.41	8.05±0.01	1242.21±5.30	1174.44±3.00	77.36±1.08	N.A.
Pb	0.46±0.00	0.98±0.02	n.d.	1.29±0.16	0.96±0.01	4.85±0.06	2
Zn	5.01±0.00	6.68±0.08	5.25±0.06	4.17±0.03	3.83±0.02	35.13±0.58	100

Notes: MFR 1985-Malaysia Food Regulation 1985, n.d.-Not detected, N.A.- Not available

During the early few months of *Pandasan* paddy growing season, water was plenty and As was not traced in the soil. However, after the same field dried up during paddy harvest season, As was traced in the soil (Table 1). In a relatively short period of time, As managed to translocate to the rice grain when soil is not waterlogged indicates amount of water in soil had an impact on phytoavailability of As. High concentration of As was detected in the rice grain of *Pandasan* variety grown at dryland due to seedlings had experienced early exposure of As phytoavailability in soil throughout the paddy life cycle. Accumulation of As in upper part of paddy plants cultivated at dryland were already detected at 2 months old (Figure 1). Paddy at early part of the life cycle are usually grown on wetter months and are harvested at drier months implicates the drier the soil environment, the more efficient As phytoavailability at sampling locations due to the physical and chemical properties of the soil.

Several paddy genotype have been identified as potential Cd hyperaccumulator (Duan *et al.*, 2017, Takahashi *et al.*, 2016). Nevertheless, Cd was not traced in soil and any parts of *Pandasan* paddy cultivated at flooded field during growing and seed production life cycle phase (Table 1). Although Cd was traced in soil and in *Pandasan* paddy cultivated at dry soil, translocation of Cd in the plant from root to grain is low as no trace of Cd was detected in the leaves and grain (Figure 1).

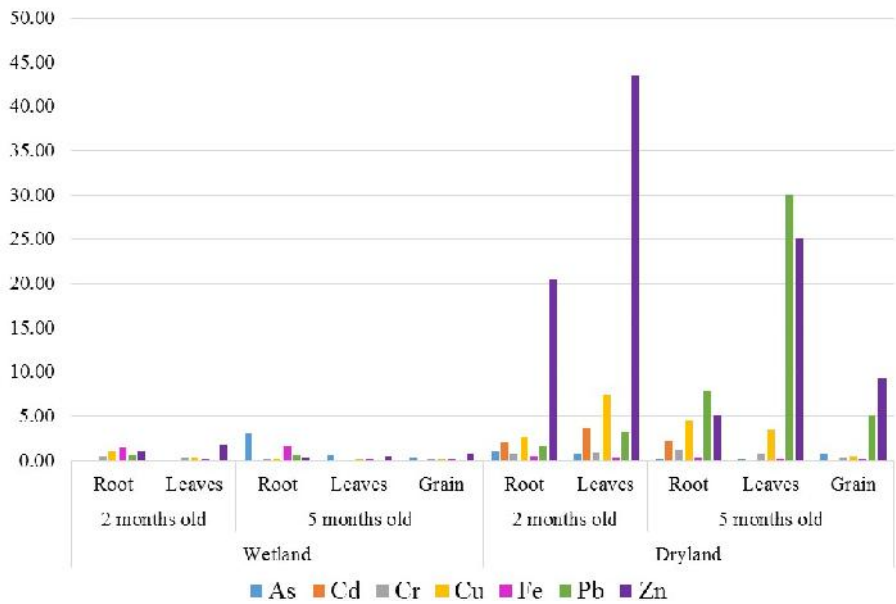

Figure 5 Enrichment factor of trace elements distribution in different parts of Pandasan paddy variety cultivated in wet and dry soil at two different sampling stages of the paddy life cycle.

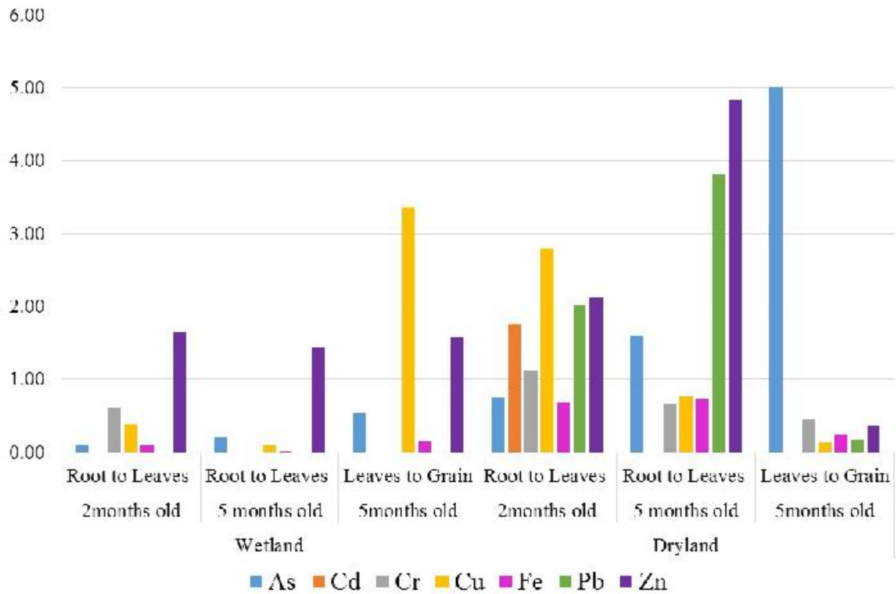

Figure 6 Translocation factor of heavy metal in Pandasan paddy variety from root to grain at two stages of life cycle phases: 2 months old (growing phase) and 5 months old (harvest phase) cultivated in different water availability environment conditions.

On well-drained agriculture areas, *Pandasan* paddy variety have the tendency to accumulate more trace elements of Pb, Zn and Cu in its biomass which is not used for consumption such as the stem and leaves (Figure 1). Thus, *Pandasan* can be a good candidate for phytoextraction of agricultural area in Crocker range which soil is not water-logged. However, pre-caution must be taken if *Pandasan* paddy is cultivated at dry area with high concentration of arsenic and lead as these two elements can translocate from root to grain in similar fashion like Zn which is highly mobile as well in this paddy genotype (Figure 2). Brown rice have higher content of As compared to polished rice (Meharg *et al.*, 2008). Concentration of As and Pb in rice grain cultivated at dry soil was above the permissible limit of Malaysia Food Regulation 1985 (Table 1). *Pandasan* paddy cultivated at flooded field was safer for consumption as none of the selected trace elements concentration exceeded the permissible limit of Malaysia Food Regulation 1985. For safer consumption, rice grain yielded from dry land could be prepared as polished rice to reduce heavy metal toxicity risk. On the other hand, rice grain yielded where heavy metal phytoavailability is low at water logged soil can be prepared as brown rice for more rich nutrient content.

Unchecked usage of pesticides or herbicides in the surrounding area can cause deterioration of productive land and long term health impact (Mohammed & Makame, 2015). Currently, slashing and burning is the common traditional method to clear up agricultural land (Hanafi *et al.*, 2009). Burning land with the aid of petrol can indirectly leave traces of Pb. A good method of disposing rice straws are required for successful reduction of heavy metal in agricultural land after *Pandasan* paddy had been cultivated considering rice straw utilization is low in Malaysia (Rosmiza *et al* 2014). Paddy waste also can be potentially utilized to clean up heavy metal by biosorption (Kumar et al 2017). Symptoms of Zn and Pb morphophytotoxicity showing on upper part of *Pandasan* paddy plant can be monitored as an alert of high bioaccumulation of these trace element on well-drained agricultural land as *Pandasan* paddy can be a candidate for lead and zinc bioindicator. Trace element uptake characteristics discoveries in *Pandasan* paddy plant can encourage multi-functions purposes not only as food resource but in soil remediation and biomonitoring activities.

CONCLUSIONS

Pandasan paddy plant's trace element uptake varies when cultivated on different soil environment at field sites. Trace element phytoavailability is more efficient in dry soil compared to wet soil of the studied field. Health risk of heavy metal toxicity can be reduced if *Pandasan* paddy is cultivated in water-logged soil compared to dry soil. Apart as a food resource for the farmers, *Pandasan* paddy can also contribute in heavy metal soil remediation for reducing Pb and Zn on well-drained agricultural land.

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