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Selected Trace Minerals Concentration Found in Two Varieties of Sweet Potatoes (*Ipomea batatas*) Grown on BRIS Soils in the East Coast of Peninsular Malaysia

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ABSTRACT Two varieties of sweet potatoes, one orange and the other purple grown on Rudua soil series and Jambu soil series, respectively, belonging to the BRIS soils were chosen for this study. These two varieties of sweet potatoes were analysed for their trace minerals composition in their respective tuber tissues. In addition, soil pH and soil moisture content were also determined. Rudua soil series had higher trace minerals content than that of Jambu soils series. The trace element concentrations in the tissues of sweet potatoes ranged from 0.037-0.130 mg/kg in Zn for 0.281-0.334 mg/kg for Fe to 0.014-0.032 mg/kg for Cu to 0.298-0.508 mg/kg for Ni and 0.746-2.16 mg/kg for Pb on dry matter basis. The soil pH is less acidic in Rudua series (5.97) compared to Jambu series (5.26), which favors higher concentrations of trace elements in the orange variety compared to Purple variety. There is also a positive correlation between nutrient concentration in the tissues of the sweet potatoes and the amount of trace minerals concentration available in the soils. This study exhibits the fact that uptake of trace minerals by the sweet potatoes is governed by the presence of these minerals in the soils, soil pH and soil moisture content.

KEYWORDS: Sweet potato; BRIS soils; trace minerals
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INTRODUCTION

Sweet potato is amongst the top seven food crops of the world (FAO, 2015) and rich in beta carotene, sugars, vitamin C, phenols and fibre (Antonious *et al.* 2011). It is planted in vast terrestrials, preferably on loamy sandy types with enough organic materials, with poor yield on heavy clay soils and moderate on peat soils (Amir *et al.* 2017). Approximately 65 % of the worlds' production of sweet potato is planted in China and 24 % in Africa (ChartsBin.com, 2018); all in the worlds' most densely populated regions. In the East Coast of Peninsular Malaysia, this crop is planted on BRIS soils, which is derived from sediment or sand from the sea that accumulated from the erosion of layers of steep cliffs by the sea during the monsoon seasons. It has high sand fractions exceeding 70-90 % in composition (Usman, *et al.*, 2014), depending on the soil series classifications (Amir, 1999). BRIS soil is usually considered as problematic and has little value for agricultural purposes because it is too sandy, weakly structured, nutrient deficient, has low water retention capacity, limited ability to support plant growth and suffer from a relatively high soil temperature (Marlia *et al.*, 2004).

Trace minerals in particular selenium (Se), copper (Cu), molybdenum (Mo) function in vast enzymatic reactions, whilst, iron (Fe) and zinc (Zn) play essential roles in protein and hormone structure and or function (NRC, 2006). Trace mineral is one of the natural resources of the earth (Lasat, 2000), which can neither be degraded nor destroyed. These resources are required in minute amounts for the maintenance of physiological functions and in high amounts, they can have very serious repercussions on our health since they tend to bio-accumulate and require long period to be excreted from our biological system (Wislocka *et al.* 2006). Human activities had been singled out as the main source of heavy metal soil contamination and was found to decrease in soils distanced away from human disturbances (Jung, 2008). Soils were found to be highly contaminated for example from lead, based on an exhaustive reviewed work by Julie & Alex (2001) and known to retard the intelligence quotient (IQ) of young children (Ndathe *et al.* 2012). Zinc helps to support the immune system, but in high amounts it can increase the risk of prostate cancer, affects copper (Cu) uptake, reduce iron (Fe) function and destroy their immune function (Ndathe *et al.* 2012). Cu had been noted to assist in the proper function of the metabolic processes but in excess may cause peroxidation of lipids (Dov & Ilya, 2017). Fe is a natural transporter of oxygen in the haemoglobin and assists in many enzymatic functions, but its accumulation in the body may cause multiple degenerative disease, liver fibrosis, heart attack and cancer (Papanikolaou & Pantopoulos, 2004). Nickel (Ni) is a cofactor for enzyme functions; present in human RNA and DNA and functions in association with these nucleic acids (Das *et al.* 2008) and excess in the body may link to cancer risk and problems associated with reproductive system (Public Health England, 2009).

BACKGROUND THEORY

Two sites were chosen, one in Pasir Putih, Kelantan, where the Orange cultivar was collected and the other located in Telong, Bachok, Kelantan; the site for Purple cultivar sampling. These two sites were located some 18 km apart and both on BRIS derived soils (Beach Ridges Intersperse with Swales) where the former yielded 5 tons per ha and the later 4 ton per ha of sweet potatoes. The former is locally classified as Rudua series and the latter as Jambu series (Paramanathan, 1978, Shamsudin, 1981 & Shamsudin, 1990). Paramanthan (1978) and Soil Survey Staff (1999), classified Jambu series as Entisol; a young profile without pedogenetic horizon, whilst Rudua as Spodosol, a more humus sandy textured soil, an acidic profile and unstructured (Mohd Ekhwan *et al*., 2009, Amir *et al.* 2017). The top soils of these two soil types are dominated by 97-98 % sand fraction, with less than 3 % clay fraction (Amir *et al.*, 2017). These soils are highly nutrient deficient, too sandy, weakly structured, have low water retention capability and acidic in nature (Amir & Wan Rashidah, 1992, Amir, *et al.*, 1993, Amir, 1999, Marlia *et al.*, 2004 & Amir *et al.*, 2017).

METHODOLOGY

Ten composite samples each of orange sweet potatoes (Orange) and purple potatoes (Purple) were randomly collected from a 2-ha plot farm, both were about 4 months old and ready for harvesting. A complete randomized sampling was carried out where a minimum of 50 tubers were sampled from each plot. In addition, 10 composite soil samples, completely randomised were also taken from each farm at a depth of 0 - 30 cm from the soil surface using hand screwed auger. The soil samples were air dried for 72 hours prior analysis in the open space, whilst the potato samples were thoroughly washed with distilled water and air dried for 72 hours. Soil pH was determined using pH meter (Hanna GLP pH meter, model: HI 111) & soil moisture was determined using JoVE Science Education Database (2018). The potato skins were then peeled and the flesh thinly sliced into 1 cm, incubated in oven at 50 °C to 60 °C for 3 days. The potato dried samples were grounded using grinding mill (Fullwell Model: CE 30B/WF) and kept in desiccators for further analysis. For analysis, the samples were prepared using wet digestion method (Matusiewicz, 2003), where 1 g of powdered sweet potatoes and 1 gm of soil sample was added with 6 ml of HNO_3 and 2 ml HCl and placed in oven at 65 °C for 3 hours.

Upon cooling, the mixture was poured into 100 ml measuring cylinder and deionized water added to 100 ml calibration mark and filtered using filter paper. The tested samples were further filtered using chromatography syringe filter and kept in a test tube and covered with parafilm sheet for storage prior to taking their readings for copper (Cu), nickel (Ni) and lead (Pb). A standard concentration of 0.5, 1.0 and 1.5 ppm were used for Cu and Ni determination, whilst for Pb the standard concentration used was 2, 4 and 6 ppm. For Zn and Fe determination, a 10^{-3} dilution was carried out since their concentrations were too high to read from the pure sample, with standard concentration of 0.2, 0.4 and 0.6 ppm and 2, 3 and 4 ppm, respectively. All the three sets of standard solutions were then tested and after right calibration curve was obtained. Ten (10) samples for each group samples (Orange, Purple, soil for Orange, and soil for Purple) were then analysed using Perkin Elmer Atomic Absorption Spectroscopy (AAS) (Perkin Elmer, Model: PinAAcle).

RESULT AND DISCUSSION

Heavy metals in the soils and their relationship with sweet potato tuber

Based on Table 1, Rudua soil series, is overall richer in all the trace minerals studied (Zn, Fe, Cu, Ni and Pb) than Jambu soil series, with amounts of 0.192 mg/kg, 0.345 mg/kg, 0.045 mg/kg, 0.636 mg/kg, 3.650 mg/kg found in the former and 0.131 mg/kg, 0.310 mg/kg, 0.025 mg/kg, 0.449 mg/kg, 1.463 mg/kg found in the latter. The higher uptake of these heavy metals is reflected by the sweet potatoes planted on these two sites, where Orange variety has higher trace minerals composition than Purple variety of 0.130 mg/kg, 0.334 mg/kg, 0.032 mg/kg, 0.508 mg/kg, 2.161 mg/kg and 0.037 mg/kg, 0.281 mg/kg, 0.014 mg/kg, 0.298 mg/kg, 0.746 mg/kg, respectively (Table 1). The high moisture content of Rudua series of 1.8 % compared to 0.7 % in Jambu series (Table 1) may assist the higher inflow of nutrients and crop yield in the orange than in Purple. A similar phenomenon was noted by Antonious *et al*. (2011). It is of worthy to note that, improved site fertility, nutrient retention, soil porosity and water holding capacity had positive bearing on productivity. In addition, Tester (1990) also noted the positive role played by increased moisture holding capacity and reduced bulk density, whilst Hernando *et al*., (1989) noted an increased soil aggregate stability, all aiding the high yield in the former soil type than the latter. It is worthy to note that soil pH of the former is less acidic (5.97) than the latter (5.26), which favours the uptake of macronutrients and its availability (Hendry & Boyd, 1997; Elliot, 2008), thus contributing to the higher yield of Orange crop in the Rudua site compared to Purple crop on Jambu site (Table 1). Elliot (2008) observed limited uptake of Fe and Zn between pH of 5.5 to 6 to some lesser extent and noted abundance in availability of Fe at pH below 5.52, especially on the acidic scale and doubled on the alkalinity scale of pH 7 onwards.

Table 1. Analysis of Variance (ANOVA) of selected heavy metals in two sweet potato cultivars (Orange and Purple) and two types of soil series; (Rudua and Jambu) between means, expressed as mg/kg (ppm) and soil moisture content in %.

Sweet Potato	Selected Micronutrients (Heavy Metals) & Soil Ph & Moisture Content						
	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	pH	moisture (%)
Orange	0.130 ± 0.004^a	0.334 ± 0.002^a	0.032 ± 0.002^a	0.508 ± 0.003^a	2.161 ± 0.012^a	-	-
Purple	0.037 ± 0.005^b	0.281 ± 0.004^b	0.014 ± 0.002^b	0.298 ± 0.004^b	0.746 ± 0.013^b	-	-
Soil Series							
Rudua	0.192 ± 0.004^a	0.345 ± 0.002^a	0.045 ± 0.003^a	0.636 ± 0.003^a	3.650 ± 0.017^a	5.97 ± 0.05^a	1.8 ± 0.03^a
Jambu	0.131 ± 0.003^b	0.310 ± 0.003^b	0.025 ± 0.003^b	0.449 ± 0.003^b	1.463 ± 0.017^b	5.26 ± 0.10^a	0.7 ± 0.02^b

Note: If the alphabet in the mean column is not the same, it is significantly different at $p<0.05$; n = 10.

Trace minerals are some of the natural resources on our earth and natural component in the soil (Lasat, 2000). These elements cannot be destroyed or degraded. Whether we realize it or not, trace minerals can sometimes get into our body from food, drinks and air (Antonious *et al*., 2011) and soil (Kabata-Pendias & Mukerjee, 2007, Kabata-Pendias & Sadurski, 2008). In small amounts, trace minerals are actually important in maintaining our physiological function, but ingesting them at higher amount can cause detrimental effects to our body (Kabata-Pendias, 2011). Trace minerals are dangerous because they tend to bio-accumulate, where they will reside in our body and take a long time to be excreted (Wislocka *et al*., 2006). Over time their amount will increase and cause heavy metals poisoning which can lead to death.

The concentration of trace minerals in a particular soil is very much influenced by human activities (Kabata-Pendias & Mukerjee, 2007). It was found that trace minerals decreased as the soil distance from human area activity is increased (Jung, 2008). For example, soils and plants can be contaminated by lead from car exhaust, dust and gases from various industrial sources such as mining (Kabata-Pendias, 1989). Furthermore, significant correlations were noticed between Zn, Fe, Cu, Ni & Pb (Table 1 & Table 2) in the sweet potatoes for all the nutrients present in the soils. These highly positive correlations are examples of synergistic relationships. For example, the presence of Zn in the potato (Orange or Purple) helps in the uptake of Fe, Cu, Ni and Pb in both soil types (Table 2 & Table 3). The same phenomenon was also reported by Seby *et al*. (2001) in the formation of some complexes of metals such as $CoSeO_3$, $MnSeO_4$, $NiSeO_4$ & $ZnSeO_4$ showing a display of their affinity to each other.

Table 2. Correlation coefficient analysis (Rs) between Orange sweet potato and Rudua soil series

Rudua Series	**Orange Sweet Potato (Orange)**				
	Zinc	Iron	Copper	Nickel	Lead
Zinc	1	0.926**	0.923**	0.989**	0.989**
Iron	0.926**	1	0.856**	0.929**	0.932**
Copper	0.923**	0.856**	1	0.933**	0.931**
Nickel	0.989**	0.929**	0.933**	1	0.999**
Lead	0.989**	0.932**	0.931**	0.999**	1

Note: ** Correlation coefficient is significant at P<0.01 level, n=20

Table 3. Correlation coefficient analysis (Rs) between Purple sweet potato and Jambu soil series

Jambu Series	**Purple Sweet Potato (Purple)**				
	Zinc	Iron	Copper	Nickel	Lead
Zinc	1	0.963**	0.928**	0.996**	0.996**
Iron	0.963**	1	0.884**	0.967**	0.971**
Copper	0.928**	0.884**	1	0.924**	0.929**
Nickel	0.996**	0.967**	0.924**	1	0.998**
Lead	0.996**	0.971**	0.929**	0.998**	1

Note: ** Correlation coefficient is significant at P<0.01 level, n=20

However, plants are known to exhibit three general uptake characteristics of trace minerals: accumulation, indication and exclusion and this phenomenon vary from one plant species to another (Kabata-Pendias & Sadurski, 2008; Kabata-Pendias, 2011). Alexander *et al.* (2006) however, observed variability uptake in trace minerals between genotypes of a specie, where low uptake was noted on legumes, moderate in tuber root and high in leafy vegetation. In another study, Peris *et al*. (2007), reported significant uptake of trace minerals (with the exception of Zn) in lettuce and to a lesser extent in artichoke. Kabata-Pendias & Sadurski (2008) & Kabata-Pendias (2011), summed up the capability of the plant mechanism to deal with the excess of trace minerals in the growth media through complexing & chelating of ions outside the plant cells, mainly in the roots, binding the ions to cell wall, by means of selective uptake, and immobilized them in various organs as immobile compounds. This phenomenon includes minerals with restricted influx through plasma membrane and also released by leaching from foliage and stems.

In addition, it has been established that the concentration of trace minerals in the soil is directly correlated to the trace minerals concentration in the plant tissue, but plant species, root zone activities, environmental conditions and addition of chelating agents may have some effects too (Tangahu *et al*., 2011). Plants are both accumulators and excluders of trace minerals, where the former survives by biodegrading the contaminants into inert forms in their tissues, whilst the latter restricts its uptake into their biomass (Sinha *et al*., 2004). It has been recorded by Ana *et al*. (2008) that hyper accumulator plants can accumulate high amounts of metal ions up to thousand parts per millions (ppm), stored in the vacuole, but sweet potato is not one of them (U.S. Department of Energy, 1994). Antonious *et al*. (2011) pointed out that plants are capable of transferring and concentrating metals from the soil, where Pb, Cd & Ni are easily accumulated in the plant tissue and capable of flowing into the human food chain and are detrimental to human health. They found that, regardless of soil treatments, the concentrations of Pb in the edible roots of sweet potatoes was significantly low, where the plant is capable of preventing the accumulation of Pb in the edible root but not in leaves, stems and feeder roots, which correlates to Pb concentration presence in the soil. However, this study exhibited very highly significant correlation ($P<0.01$) between sweet potato roots with that of the soils (Table 2 & Table 3).

Heavy metals concentrations in the sweet potato

Based on this study, the trace minerals concentration in the tissue of sweet potatoes range from 0.037-0.130 mg/kg for Zn to 0.281-0.334 mg/kg for Fe to 0.014-0.032 mg/kg for Cu to 0.298-0.508 mg/kg for Ni and 0.746-2.16 mg/kg for Pb on dry matter basis (Table 1). All these range of figures were considered well below the critical level of 0.1 mg/kg set by Joint FAO/WHO Food Standards of Codex Alimentarius Commission (2006), with the exception of Fe, Ni and Pb. In contrast, China Environmental Protection Administration set the maximum permissible level of Cd, Cr, Cu, Ni, Pb, and Zn at 0.2, 0.5, 20, 10, 9, and 100 mg/ kg on dry basis, respectively, for their vegetables and fruits products (Khan et al., 2008). However, Alexander *et al.* (2006) pointed out that the critical level in the plant tissue for Cu to be 15-20 mg/kg, Ni 20-30 mg/kg and Zn 150-200 mg/kg. Meanwhile, in Brazil, Guerra *et al*., (2012), illustrated the content of Cd, Ni, Pb, Co and Cr in three varieties of sweet potatoes to contain 0.11-0.14 mg/kg, 0.15-0.26 mg/kg, 0.43-0.52 mg/kg, 0.49-0.55 mg/kg and 0.04-0.06 mg/kg, respectively. Based on this study (Figure 1), our sweet potato contains one-fold higher in Ni (0.298-0.508 mg/kg) concentrations compared to Brazilian data (0.15-0.26 mg/kg) and higher by 2-4 folds for Pb content (0.746-2.16 mg/kg) compared to 0.43-0.52 mg/kg), respectively. The above results are not surprising since Ni and Pb are found in high concentrations in BRIS soils, amounting to 0.449-0.636 mg/kg and 1.463-3.65mg/kg, respectively. It is interesting to note that, Pb has been found to have no biological role in animals, plants and microorganisms (Antonious *et al*., 2011), but can bond with the sulfhydryl group of proteins, thus disrupting the many biological and metabolic activities of proteins; causing cancer in kidneys of the rodents.

Interestingly, trace minerals in particular Zn, Cu and Ni are the essential constituents of pigments and enzymes in plants but toxic in excess due to disruption of its enzymatic function (Bahula *et al*. 2009). Trace minerals are found to be non-biodegradable and capable of accumulating in human vital organs (Demirezen & Aksoy, 2006) and lead to progressive toxic effects if consumed. It is also found to be toxic to soil microorganisms when present in excessive concentrations

(Chakrabarti *et al.*, 2005). Pandey and Sharma (2002) observed the wilted appearance of Ni treated plants, when water was not limiting in the rooting medium. This observed phenomenon can be due to impediment of water movement from roots to the leaves, possibly due to biological reactivity in oxidation-reduction reaction, leading to generation of reactive oxygen species (ROS). The ROS are known to damage the functioning of cellular membranes, thus affecting the influx and the long-distance transport of water in plants.

CONCLUSION

Based on this study, the trace minerals concentrations in the tissue of sweet potatoes range from 0.037-0.130 mg/kg for Zn to 0.281-0.334 mg/kg for Fe to 0.014-0.032 mg/kg for Cu to 0.298-0.508 mg/kg for Ni and 0.746-2.16 mg/kg for Pb on dry matter basis. Overall, Rudua soil series is richer in trace minerals (Zn to Fe to Cu to Ni and Pb) than Jambu soil series. The higher uptake of these trace minerals is reflected by the sweet potatoes planted on these two sites, where Orange variety has higher trace mineral figures than Purple varieties. The other interesting factor is the moisture content of Rudua is much higher than the Jambu series, thus giving rise to higher yield of 5 tons / ha of orange sweet potato on the former soils and only 4 tons of Purple variety on the latter soil series. The soil pH is less acidic in Rudua series compared to Jambu series, which again favours higher concentrations of trace minerals in the Orange variety compared to Purple variety, a contributing factor to the high availability of these nutrients in the soils.

The uptake of trace minerals by the sweet potatoes is governed by the presence of these minerals in the soils, the soil pH value, the soil moisture content, the soil porosity and the soil aggregates. Further studies should be suggested on these soil physical characteristics, since BRIS soils is extensively available in the east coast and widely use in the tobacco cultivation. The usage of BRIS soil, which is classified as problematic soils, must be extended to cover wider range of food crops, which in turn will alleviate the income of the local farmers and eventually limit the movement of the younger generations to big cities.

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