AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

MINERAL MICRONUTRIENT DENSITY CHARACTERIZATION USING ENERGY DISPERSIVE X-RAY FLUORESCENCE (XRF) ANALYSIS IN FOUR ON-FARM KENYAN WILD AFRICAN FRUIT TREE GERMPLASM

Akundabweni LSM[1*], Munene RW[2], Maina DM[3] and JM Mangala[3]

Shadeya Akundabweni

*Corresponding author email: proflevi@uonbi.ac.ke or proflevimudogo@yahoo.com

[1]Department of Plant Science & Crop Protection, University of Nairobi, P.O. Box 30197-0100 Nairobi, Kenya.

[2]World Food Programme (WFP) Nairobi-Kenya.

[3]Institute of Nuclear Science and Technology, University of Nairobi, P. O. Box 30197- 00100 Nairobi, Kenya.

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

ABTRACT

Kenya has over 400 marginalized indigenous fruit species. A majority found in natural habitats are allegedly high in micronutrients that could help mitigate the prevailing micronutrient nutrahealth deficiencies. Amplifying their nutrahealth value more as nutraceutical than wild species, and coupled with local level community-centred promotion for use and conservation, could stimulate the uncommon opportunities for decentralized and locale-specific community use and conservation. Thus conservation-by-use could enlarge the nutrahealth security basket as well as mitigate loss of the vanishing fruit species. In retrospect, value-adding nutrahealth research is needed to change the un-informed mind. Thus, the objectives of the study were to: (1) tag Mineral-Referred sites (MRS) influencing Fruit Mineral-Density variation (FMDVAR) among Grewa, Rhus, Boabab and Jackfruit accessions; and (2) apply a nutrametric value (grading) test to classifying FMD variation (FMDVAR) within the realm of nutraceutical food, nutrition and health promise. Fruit portions with their tree trunk adjoining soils were collected in 2003/04 from Kanduyi-Chwele-Nalondo (Bungoma) transect; Maseno-Esivalu (Maseno); and Kaseme-Masongaleni (Kibwezi) and subjected to XRF analysis at the Institute of Nuclear Science and Technology in the University of Nairobi. A Clustered-Bar-Graphing test was used to obtain Ca, K, Fe, Zn, Cu, Mn as variation-picking elements which were turned into MRS X-variables upon which fruit species mineral-density variation was determined. Significant ($p \leq 0.05$) FMDVAR x MRS and phyto-region x FMDVAR interactions were detected. Rhus spp had the highest Fe-Mn > Grewa spp > Jackfruit > Ficus > Boabab spp depending on locations they were collected from. In that order, Ficus showed the highest iron-manganese but had the lowest Zn-Cu. Jackfruit, with Fe-Mn third in line, had highest Zn-Cu. There was no accession with 'all-winner' elements. In density terms some minerals were top while others were variably low. High uptake-ability of elements in the tree species such as demonstrated by Rhus may be indicative of their soil-mining (a depletion effect) and/or fruit accumulation (a nutra-health plus) tendency. On the overall, nutrametric valuation (NTV) confirmed that Rhus and Ficus had highest fruit micronutrient variation relative to Jackfruit and Boabab. NTV clusters did not show a one-to-one soil-to-plant element matching between plant and soil mineral content. Plant micronutrient patterns show the potential for exploiting the indigenous trees for development of nutrahealth cropping.

Key words: XRF, Micronutrient Density, African Fruits

INTRODUCTION

In the context of micronutrient-based food security, XRF analysed differences across regions, species and crop types point to the robustness of XRF spectroscopy as a planning tool for mineral-rich micronutrient de-marginalization in the underutilized/neglected or orphaned indigenous fruit genetic resources. Such tools have potential to contribute to the popularisation, exchange of seed and future commercialization of the mineral-rich variants. Furthermore, micronutrient work is required for awareness creation to promote the potential multi-purpose benefits especially in the arid and semi-arid areas where children and adults snack on natures' phytodiversity or turn to the said resources during hunger periods. The multi-elemental aspect of this technique is novel in the sense that it generates data for several elements at once; an aspect difficult to achieve with conventional wet chemistry based techniques. The desired mineral macro and micronutrients can be targeted for nutraceutical phyto-diversity variation among unknown populations. Such phyto-diversity is of importance in plant domestication and/or commercial product development.

The African Cereal-Vegetable-Fruit culti-groups constituting 7,100 species in Kenya are core to Kenya's indigenous food habits nutrahealth and are folklore. The yet to be fully utilized 400 fruit species (Maundu- personal communication) cultigroup genetic resource is a potential source of wood fuel or timber, health remediation (medicinal), perennial yielding, eco-aesthetic, socio-economically aligned and as a source of food and feed [1]. Mitigation of HIV/AIDS severity, cardiovascular diseases, diabetes and other adverse consequences of the nutrition transition have been cited in instances of the Cereal-Vegetable-Fruit potential [2, 3, 4]. However, much of the potential, particularly the micronutrient density still remains unknown leading to an imbalance between non-food tree arable efforts and agroforestry In effect, beneficial effects to vulnerable groups such as children, expectant mothers and the poor still remain wanting. The following is a brief on the tree species and fruit potentials.

a) Rhus natalensis (Swahili:- mvunja kondo, mti shangwe, mkono chuma)- Family: Anacardiaceae

The tree is a native to Kenya and also extents to Republic of Congo, Ethiopia, Guinea, Saudi Arabia, Somalia, South Africa, Sudan, Tanzania, Uganda. Botanically, Rhus natalensis is a shrub 2-3 m high or a small tree up to 8 m tall; bark of the branchlets greyish or white and older ones dull grey, lenticillate and rough. Its fruit is a glabrous drupe, oblong-reniform, 5-6 mm in diameter. Ecologically, *R. natalensis* is normally found in deciduous and evergreen bushland and woodland, riverine associations, forest edges, often on well drained slopes. It also commonly occurs in coastal bush, thickets and forest. Its biophysical limits are in the elevation range of 0-3 000 m above sea level and a mean rainfall between 1000 and 1400 mm. The tree prefers clay soils but can grow on various soil types.

The sour tasting globose fruits have an edible pulp. The bark can be made into tea, the roots into soup and tender leaves and shoots chewed as food. Its foliage provides fodder. Other items curved from its wood include: household items, agricultural implements and tool handles. The root bark is a source of dye tannin or dyestuff. Rhus spp is highly irritant and vesicant. It is also used as a medicinal plant; the branchlets of this tree are used as toothbrushes, the root decoctions are taken orally to stop diarrhoea, the branch decoctions are administered orally for stomach upset, the leaves are used in treating coughs and stomach ache, the root decoction also forms part of a medicine for hookworms, and the leaf infusion is used in preparing a cough mixture.

R. natalensis helps in soil conservation on slopes as well as a cool shade. It is a good garden tree beautiful with beautiful fresh foliar growth red in colour. Wood from *R. natalensis* is used in making fence poles and in some parts of East Africa. It is used in the ritual treatments for neonates in an immunization-like manner. The plant is naturally seed-propagated.

Figure 1: Rhus natelensis growing in Masaai Land

(b) Grewia tenax (Common name: Mulawa (Kamba) for a similar species)

G. tenax has often been cited as a prime candidate for domestication as a useful horticultural plant. One major factor hampering this development is the limited and scattered knowledge available on this species.

Biology: Formerly placed in Tiliaceae family, it has more than 400 species worldwide. It is native to Africa, Asia and Australia. *Grewia tenax,* among them, is a fruit-producing shrub found in Kenya. In Kenya, its shrub populations are wild and annual fruit yields are erratic and variable due to increased pressure from agriculture, drought, and predation. Ecologically, it can withstand environmental stress more easily than annual crops and thus makes an important contribution to sustainable production without needing expensive inputs of water or fertiliser. In terms of its socio-economic value, the tree is described as a prime candidate for domestication and

commercialisation as a new crop, as for example, for the semi-arid regions of the Sudan [5]. It is said to regenerate well, and is traditionally protected during clearing and favoured by farmers.

Locally, where it is present as in parts of the arid Sudan, it is used as food. However, most of fruit production results from gathering activities. Its folk medicine value has been documented. Roots, leaves, juice and fruit decoctions have been used in Africa and Southeast Asiatic countries for a variety of medical purposes. Added aqueous extract (10 mg ml^{-1}) of *Grewia tenax* fruit seems to favour iron transfer (absorption) from the mucous side toward the serous one in as little as 5 minutes of incubation time in stomach, duodenum and jejunum. Higher doses (20 and 30 mg ml^{-1}), however, may significantly reduce iron uptake suggesting a probable toxic effect of this extract [6]. Internationally, it has great export potential for use not only as food but also in pharmaceutical industries.

Figure 2: Grewia tenax

c) *Artocarpus heterophyllus* Lam. [7, 8]; common name: Jack fruit

It is a monoecious fruit tree producing male and female flowers, its fruit is the largest tree-borne in the world in the Moraceae family. It possibly originated in the rain forests of the Western Ghats in India. It is now both naturalized and cultivated in many tropical countries as a wet-environment adapted fruit tree. It thrives best at <1000 m above sea level on almost any type soil except under water logged and poor drainage conditions. Fruits weigh up to 50 kg and 60 – 90 cm in length and when mature produces up to 700 fruits per year, each weighing 0.5 to 50 kg with 100 - 500 seeds in a single fruit. Socio-economically, it is described as the fruit of the Future for its aesthetic, good yielding, highly nutritional and environmental value. Due to its socioeconomic multipurpose importance in Bangladesh, it is declared a 'national fruit'.

The fruit was captured by the corresponding author to be a popular snack for young school children in Iganga of Uganda (Figure 3). The pulp of the young fruit is cooked as a vegetable, pickled or canned. Pulp of ripe fruit is eaten fresh or made into various local delicacies including chutney, jam, jelly, and paste, or preserved as candies by drying or mixing with sugar, honey or syrup. The pulp is also used to flavour ice cream and beverages, made into jackfruit honey, reduced to concentrate or powder, and used for preparing drinks. Seeds can be eaten boiled, roasted or dried and salted as table nuts, or they can be ground to make flour and blended with wheat flour for baking. Young leaves are pruned for fodder. Different parts of the jackfruit tree have medicinal properties. Pulp and seeds are used as a tonic, the warmed leaves have healing properties if placed onto wounds, and the latex, mixed with vinegar promotes healing of abscesses, snakebite and glandular swellings. Wood has a sedative effect. Its pith is said to cause abortion. The root is used as a remedy against skin diseases and asthma, and its extract is taken in cases of fever and diarrhoea. The timber is a medium hardwood with desirable characteristics in making furniture, oars, implements and musical instruments. A yellow dye can also be extracted from the wood particles and used to dye cotton. The latex which flows from all parts of the plant when injured is also used as adhesive. The resins within the latex may also have some value.

Figure 3: The Jackfruit tree is a multi-purpose species providing food, timber, fuel, and forage, medicinal and industrial products (Photo by author Akundabweni).

d) African Cluster Fig (*Ficus drypondtiana/ F. benjamina)*

Is a genus of about 800 species of woody trees, shrubs and vines in the family Moraceae and is native throughout the tropics with a few species extending into the warm temperate zone (Figure 4).

Figure 4: Fruit tissue appearance of a Ficus species

Of interest is the African Cluster Fig *(Ficus drypondtiana)* at present not yet well categorised. A medium size tree, it bears clusters of grape like figs in bunches, which are described as being very sweet. The fruit of many species are edible though not widely consumed. Fruit trees under consideration are more likely to better survive drier conditions than most cereals and vegetables are marginal. This is evident from the limited knowledge that exists as to their yield potential, socioeconomic value, health remedy, wood value and/or industrial value.

e) Adansonia digitata (Baobab genus) [9, 10]

Boabab tree is a typical occurrence along the greater Kibwezi Area in Makueni District- Kenya (Figure 5).

Figure 5: Boabab tree

The only African species is the Baobab *Adansonia digitata*. Formerly in Bombacaceae, it has eight species that are native to tropical Africa. The tree bears large whitish flowers which open at night. The fruit grows up to a foot long. The fruit yield potential in the species is yet to be known. For its food-feed value, the fruit contains tartaric acid and vitamin C that can either be sucked, or soaked in water to make a refreshing drink. Such a juice is common in Kordofan, Sudan. The seeds can also be roasted and ground in powder to make a coffee-like drink.

Fresh baobab leaves provide an edible vegetable similar to spinach, which can be boiled and eaten. Indeed, the baobab leaf is a good source of essential minerals such as Ca, Fe, K, Mg, Mn, Mo, and P [11]. Therefore, the baobab leaves can serve as a protein and mineral source for those who live in semi-arid areas. Leaves are also used medicinally to treat kidney and bladder disease, asthma, insect bites, and several other maladies. Industrially, the bark can be pounded to make rope, mats, baskets, paper and cloth and glue can be made from the pollen.

In retrospect to the above, the objectives of the study were: (1) to tag Mineral-Referred sites (MRS) influencing Mineral-Density variation (FMDVAR) among

Grewa, Rhus, Boabab and Jackfruit accessions; (2) to apply a nutrametric value (grading) test to classifying FMD variation within the realm of nutraceutical food, nutrition and health promise. Energy Dispersive X-Ray Fluorescence (EDXRF) analysis as a fast mineral-rich variant tracking means was used to determine the micronutrient density status among Grewa, Rhus, Ficus and Jackfruit fruits

MATERIALS AND METHODS

Sampling regions

Fruit portions with their tree trunk-adjoining soils were collected in 2003/04 from the following stretches: Kanduyi-Chwele-Nalondo (Bungoma), Maseno-Esivalu (Maseno) and Kaseme-Masongaleni (Kibwezi). Bungoma sites (1,370 masl altitude) fall in the Mt. Elgon phyto-region within 0^o 32′ N and 34^o 33′ East. The collection sites have a well distributed mean annual rainfall of 1200-1800 mm with 500-100 mm during the long rains and 430-800 mm as short rains seasons. The area soils are deep, moderate to deep red -reddish brown Ferralsols [12]. Maseno sites are within the Lake Victoria Basin. The Basin sites (1,463 masl) lie within 0° 38′ S and 34° 35′ E with a bimodal rainfall averaging 1,100-1,500 mm annually [12]. Kibwezi sites (914 masl) fall within the Eastern region located on 2° 35′ S and on 32° 28′. The Kibwezi soils are mostly chromic well-drained, moderately deep-to-deep red, reddish brown friable firm sandy clay-to-clay Luvisols (Figure 4). Annual rainfall is bimodal with 500-1300 mm average range [13].

Sampling

Fruit portions of the above described species with their tree trunk adjoining soils were collected in 2003/04 from where-found-and-as were-found within the Kanduyi-Chwele-Nalondo (Bungoma) transect; Maseno-Esivalu (Maseno) and Masongaleni, (Figure 6). Each site consisted of 3 different farm units from which samples were collected and sun-dried for 3 days on dry polythene covers to avoid extraneous metal contamination.

Energy Dispersive X-ray Fluorescence (XRF) Analysis

Samples were oven-dried at 80°C for 18-20 hours. Each sample was repeatedly ground to less than 50 µm sieve-size, weighed to between 100 - 200 mg cm^{-2} from which three pellets of 2.5 cm diameter were made in a pellet-pressing machine under 10 - 15 ton of pressure. Each pellet was irradiated with a primary radiation from a Cd-109 radioactive source for a period of 2500 seconds. The characteristic x-rays emitted by the elements in the sample were detected by a liquid nitrogen cooled Si(Li) detector. The resolution of the Si (Li) detector used was 195 eV for manganese (Mn) Kα line at 5.9 keV. A computer based multi-channel analyser was used for spectral data collection and storage while the Quantitative X- ray Analysis System (XQAS/AXIL), a software programme supplied by the International Atomic Energy Agency (IAEA), was used for data deconvolution. For each pellet, two irradiations were done; sample alone and sample with a molybdenum target on top. These two measurements were then used to calculate the absorption corrections.

Computation of geometric means and accession scores based on mineral concentrations of samples

Mean and standard deviations of mineral concentrations for each sample accession were computed. Clustering patterns of sampled material were computed according to the association principle described by Cooper and Schindler [14]. As a first step, data were subjected to a Clustered Bar Graphing test so as to identify variation-picking element(s) (Figure 7).

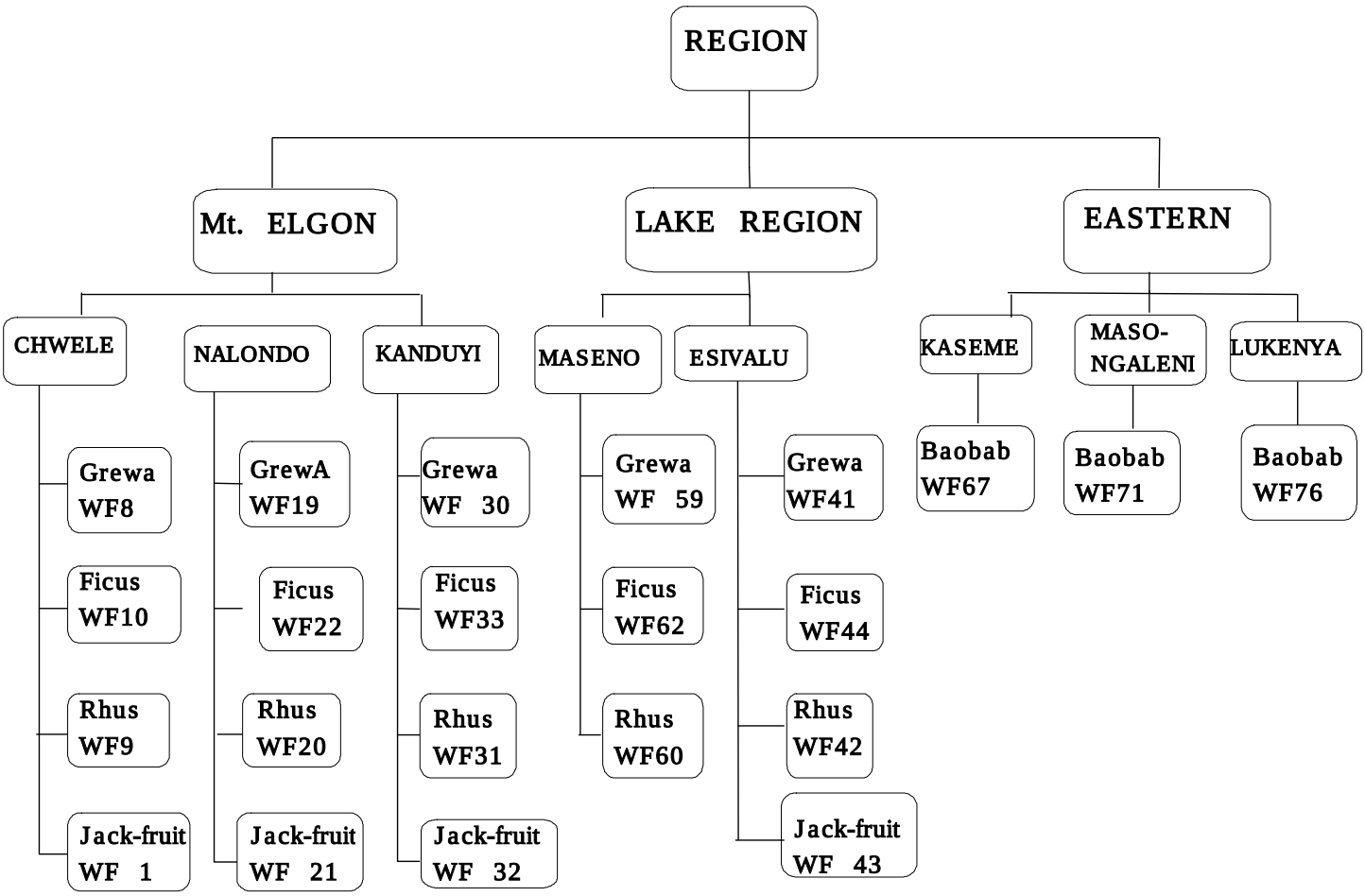


Figure 6: Germplasm sampling design

A Clustered-Bar-Graphing test was used to obtain Ca, K, Fe, Zn, Cu, Mn as variation-picking elements, which were turned into MRS determinants of the Fruit species Mineral-Density variation.

Secondly, Analysis of Variance (ANOVA) tests were undertaken with each variation-picking element treated as an independent variable upon which the fruit species accession density differences were distinguished. Thirdly, clustering patterns of

sampled material were subsequently computed according to the association principle described by Cooper and Schindler [15]. First: the series of sampled accessions (for plants and soils, separately per site) were arranged in ascending order to obtain the range of mineral concentration values from smallest to largest concentration values for interval categorisation; Second: Microsoft Excel IF logic test was then used to generate **5** interval categories along the minimum-maximum range of data. The codes subsequently assumed the place of the actual concentration values with code **1** representing the highest density up to the lowest as **5**; Fourth: By this as a last step, exclusively developed by the Institute, all variation-picking elements for each accession were subsequently collapsed into a single nutrametric valuation (NMV) or grading test via a series as shown in Figure 7.

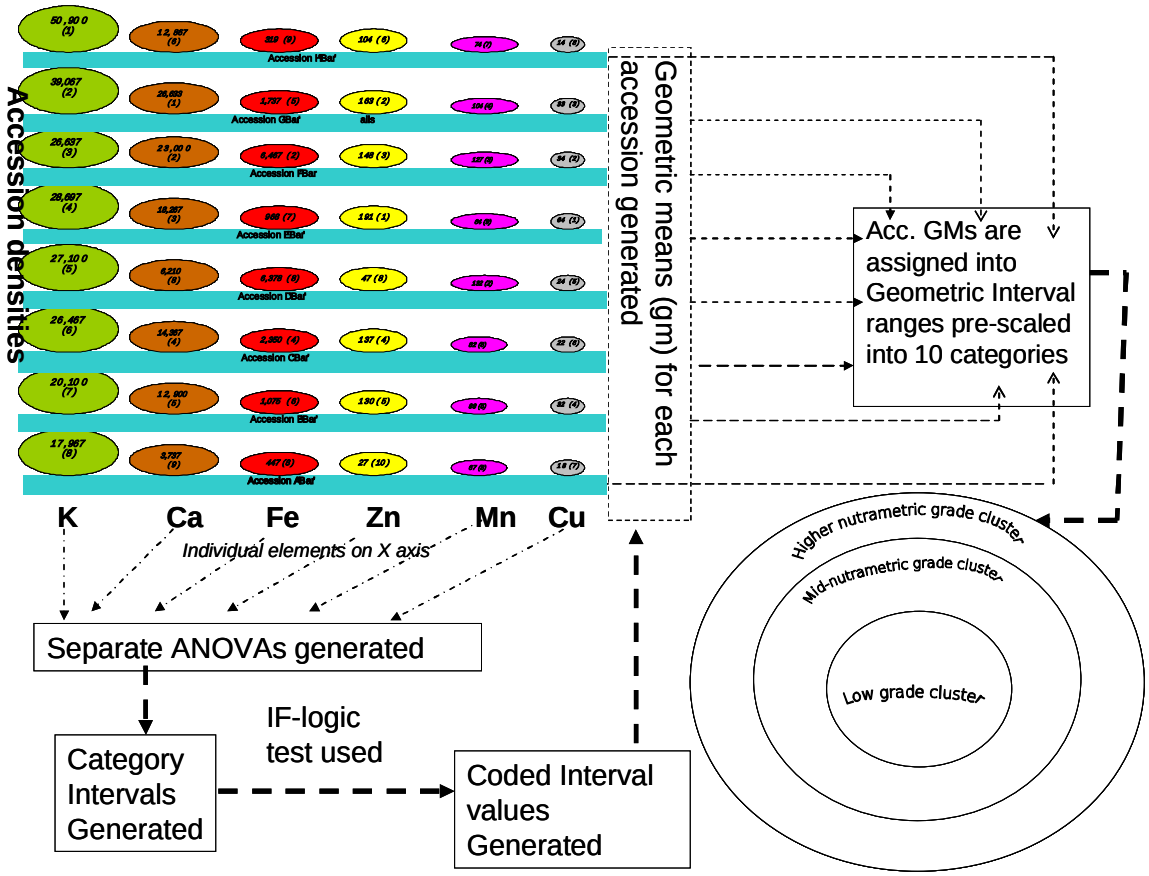


Figure 7: Steps following the Laboratory Phase for relating Various Accession concentrations (densities) to selected elements. Horizontal bars represent various accessions upon which the eyeball displays of respective concentration are stacked.

RESULTS

Table 1a presents five separate ANOVAs, each indicated by respective individual element as a determinant of FMDVAR. Each of the element, as a determinant, significantly 'sensed' concentration differences among the fruit accessions (see ANOVA 'a' to 'f' in Table 1a).

Significant ($p \leq 0.05$) mean mineral densities among species as separated by Duncan test were detected (Table 1b). For instance, among species, potassium was highest in two accessions of Ficus, namely: the Esibalu WF44 (34,500 ppm) and the Maseno WF62 (32,400 ppm) accessions both of the Lake Basin area. The same accessions also contained the highest calcium (8,137 ppm). Generally, Ficus accession WF44 was not only highest in K and calcium but also in zinc and copper (Table 1b).

Species' potassium was generally 5-fold higher than tissue calcium. Single mineral factors had the highest density effects as follows: 268 ppm for Fe in Nalondo Rhus-WF20 from Bungoma and 584 ppm for manganese in Esivalu Rhus-WF42 accessioned from the Lake Basin. Generally, zinc concentration was lowest in all fruits at < 12 ppm (Table 1a). It is worthy noting that a single-element-variant-determining strength by the Clustered-Bar-Graphing test approach alone is itself insufficient to characterize a total phenotype given that species were 'imperfect' in element density equality as no accession scored on all high 'top' or on all low 'bottom' for any element influencing FMDVAR.

Micronutrient density in fruit due to a significant ($p \leq 0.001$) MRS type x MINERAL type x SPECIES type revealed Rhus with highest Fe in the Esivalu-Kanduyi-Nalondo accessions but lowest in Maseno-Chwele accessions. The Maseno Jackfruit had the highest Fe compared to other sites (Fig. 12). Generally, copper and zinc, on the other hand, were un-affected by a site factor in the following order Rhus (Figure 8), Grewia (Fig. 9), Jackfruit (Fig. 10), Ficus (Fig. 11) and Boabab (Fig. 12).

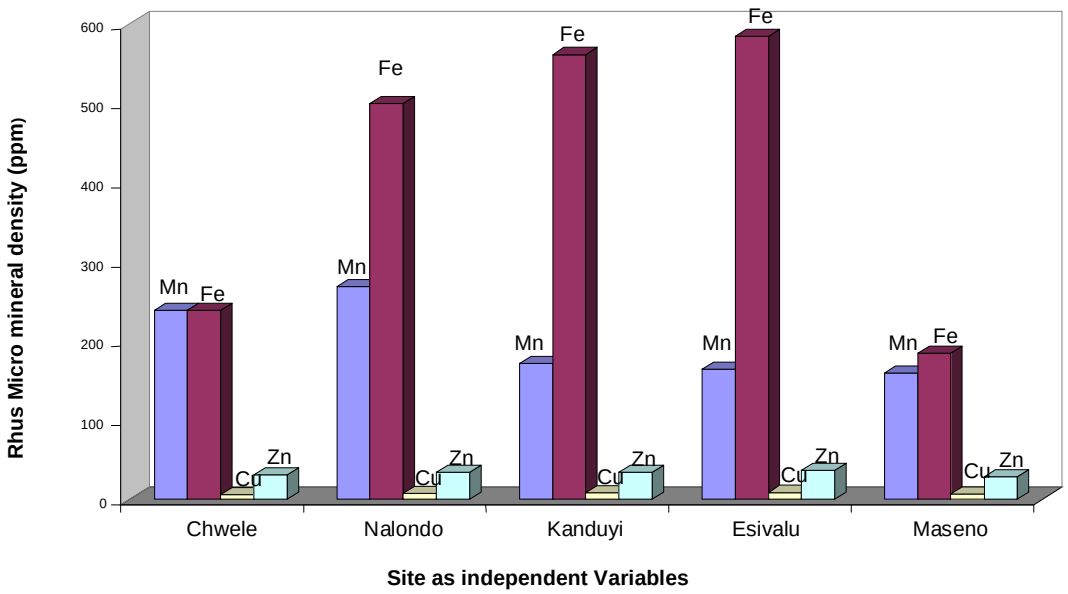


Figure 8: The MRS-dependent Rhus Fruit Micronutrient Density Variation showing high Fe-Mn (590-270 ppm) and low Zn-Cu pairs (~ 2 ppm)

The MRS-dependent FMDVAR elicited: (a) high Fe-Mn (590-270 ppm) and low Zn-Cu pairs (~ 2 ppm) in FMDVAR in Rhus spp; (b) high Fe-Mn (245 -100 ppm) and low Zn-Cu (~45 ppm) in Grewa spp; (c) 165-65 ppm and ~18ppm of Fe-Mn and Zn-Cu respectively in Jackfruit; (d) 120-60 ppm and 50-16 ppm in Ficus; and (e) 70 -55 min ppm and ~10 ppm in Boabab spp. Masongaleni Boabab fruit accession was the one with the highest Fe (Figure 12). In that order, Ficus showed the highest iron-manganese but had the lowest Zn-Cu. Jackfruit, a third next in Fe-Mn, however had highest Zn-Cu.

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

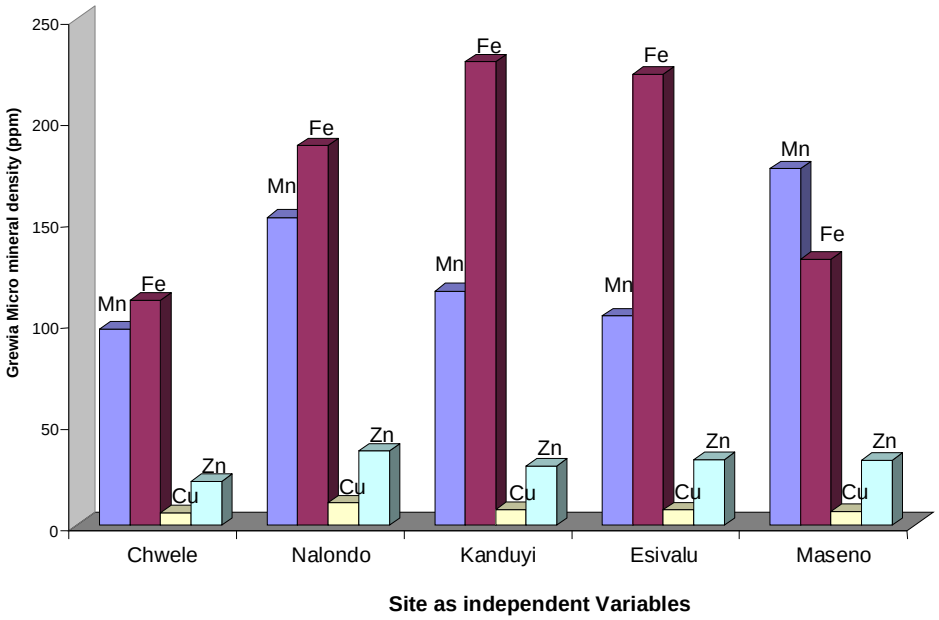


Figure 9: The MRS-dependent Grewia Fruit Micronutrient Density Variation showing high Fe-Mn (245-100 ppm) and low Zn-Cu pairs (~ 45 ppm)

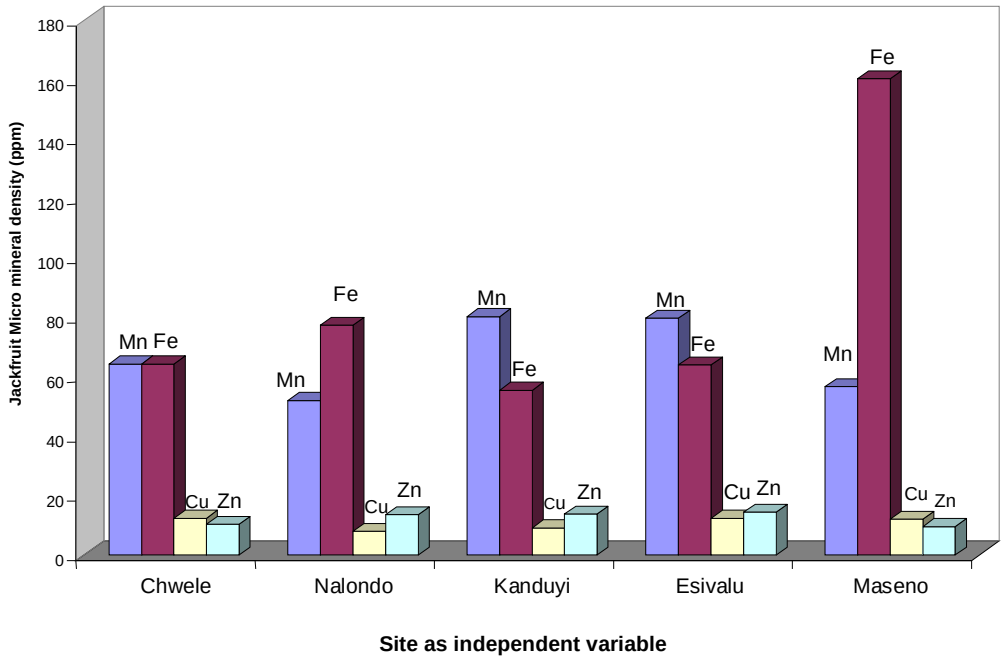


Figure 10: The MRS-dependent Jackfruit Fruit Micronutrient Density Variation showing high Fe-Mn (165 -65 ppm) and low Zn-Cu (~ 18 ppm)

AJFAND ONLINE
Volume 10 No. 8
August 2010
ISSN 1684 5374
Peer Reviewed
AFRICAN JOURNAL OF FOOD AGRICULTURE NUTRITION AND DEVELOPMENT

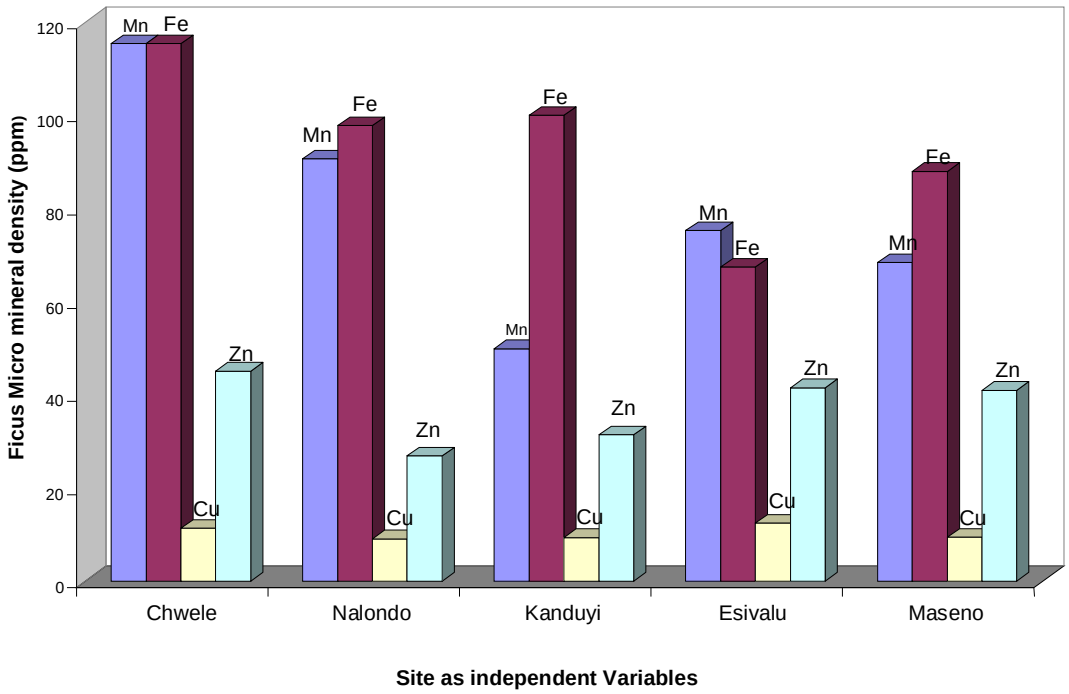
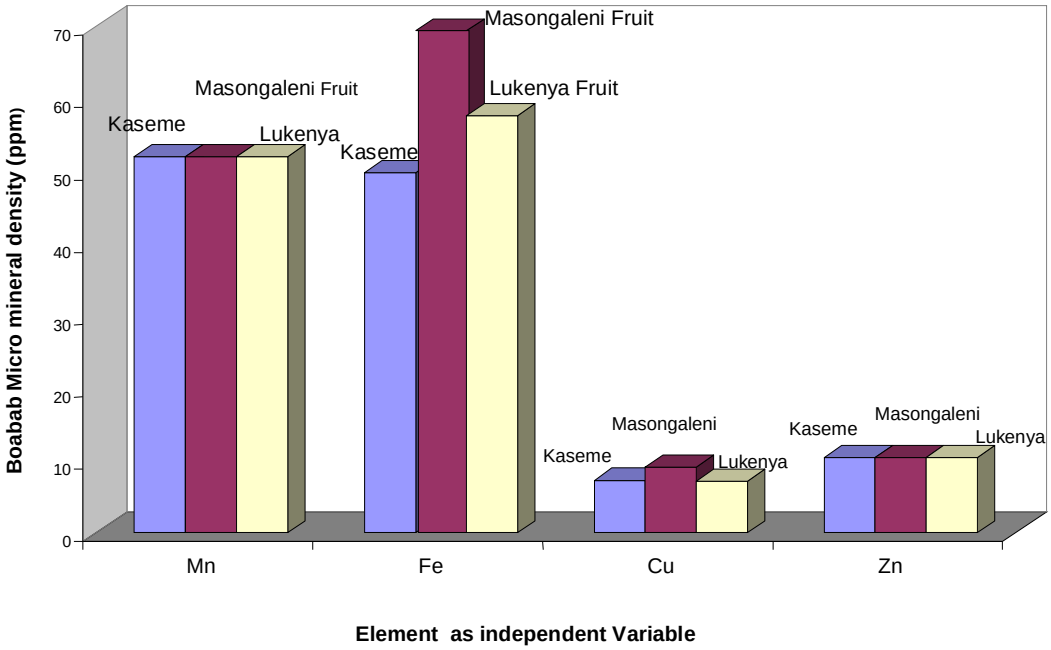


Figure 11: The MRS-dependent Ficus Fruit Micronutrient Density Variation showing high Fe-Mn (120-60 ppm) and low Zn-Cu (5-16 ppm)

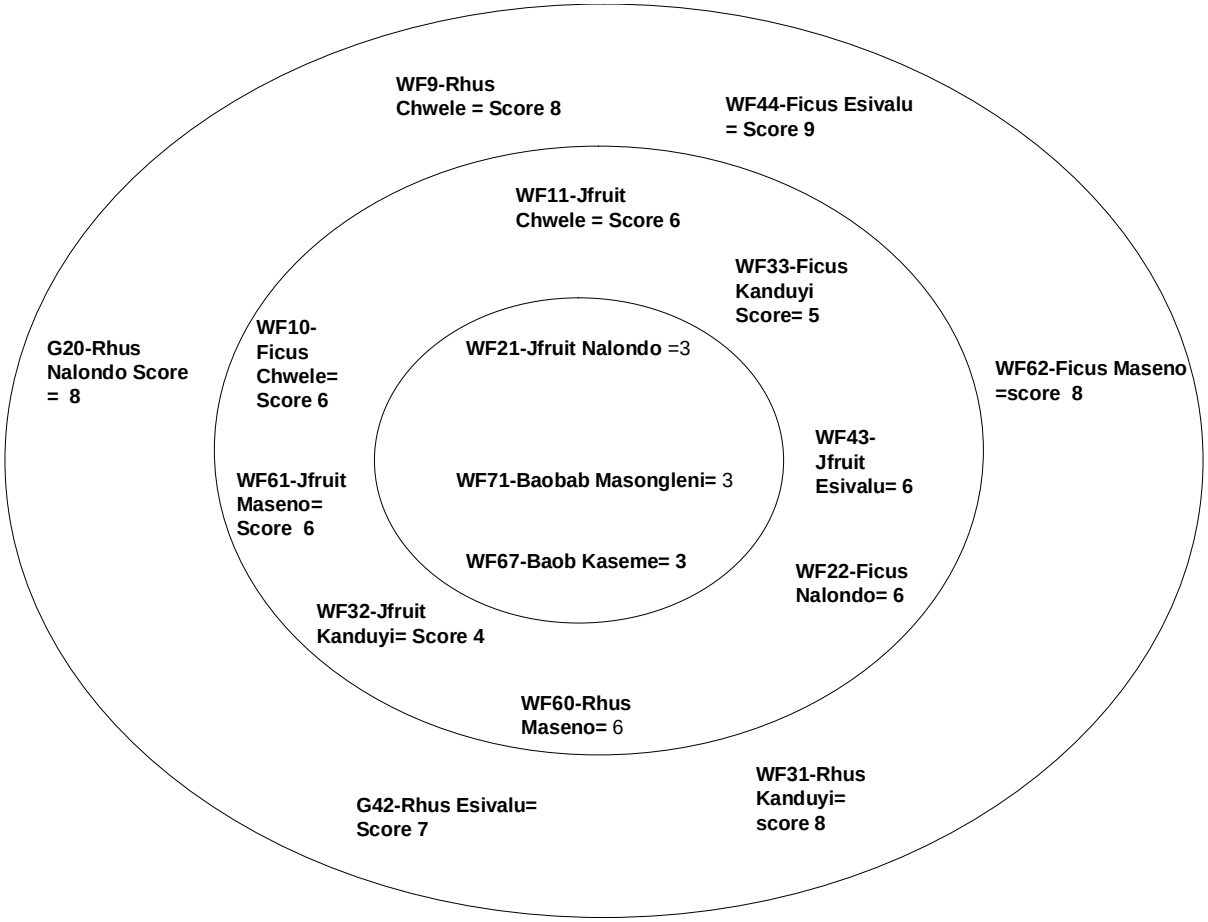
Fruit calcium was significantly ($p < 0.05$) correlated to fruit iron (Pearson r = 0.66) and fruit zinc (r=0.72). Other Pearson correlations although significant were r< 0.50 (Table 3).

A nutrametric value (NTV) graded variation is as shown in Figure 13. Based on a geometric mean scale of 1- 10, Rhus and Ficus accessions from western Kenya (Maseno and Bungoma areas) revealed the highest nutrametric grade potential lying between scale 9 and 6 and accession Ficus WF-44 dominating.



Figures 12: Fruit Micronutrient Density Variation in Boabab due a significant ($p < 0.001$) Mineral x Site Interaction

Generally, NTV clusters (Figures 13 and 14) did not show a one-to-one soil-to-plant element matching between plant and soil mineral content. Correlations between plant mineral and total soil mineral concentrations are normally poor.



Legend: Scale 9-8 =Top Nutrametric Grade; 7–5=Midway Nutrametric Grade; 4-1 = Lowest Nutrametric Grade

Figure 13: Micronutrient density grade (NTV) clusters for various fruit accessions

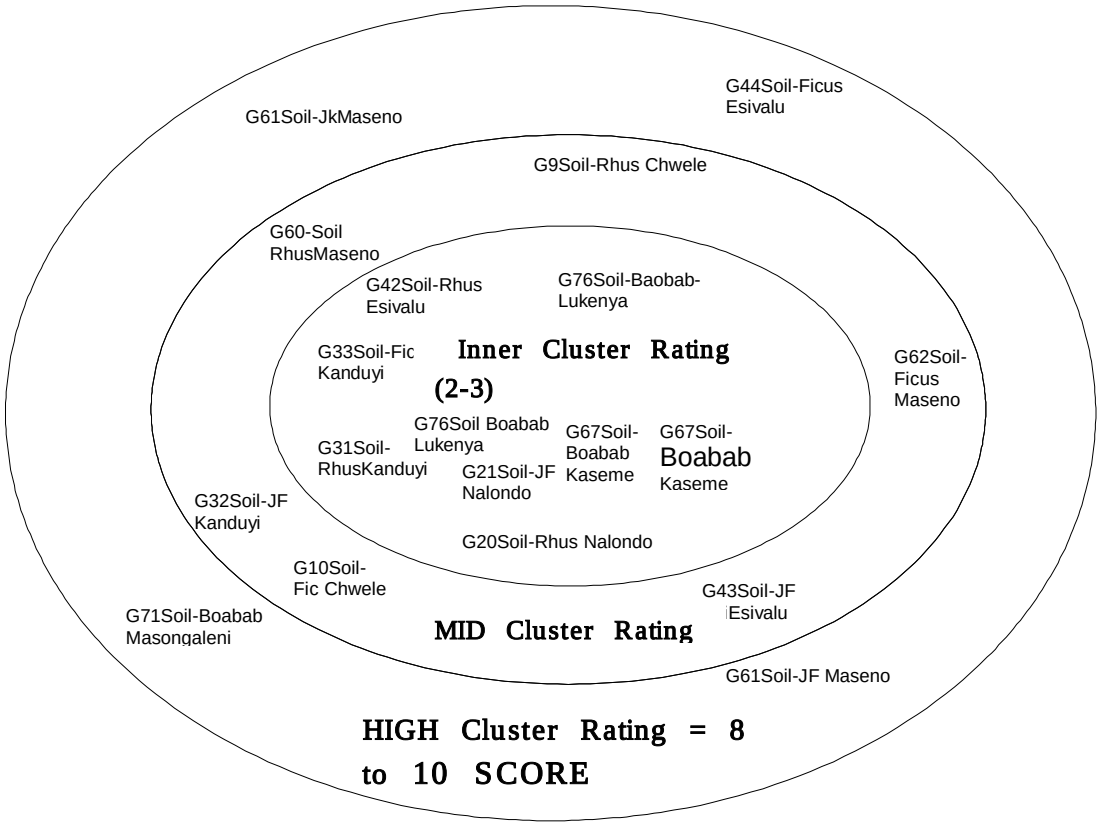


Figure 14: Variant (phenotypic) placement under three grade clusters (layers)

DISCUSSION

Potassium and copper densities were several-fold high in fruit tissues than in the accompanying soil (Table 4) possibly due to their effective element uptake-ability. It is, however, unlikely that the uptake-ability is root-length dependent as the same tendency was apparent in sorghum accessions similarly analysed. Equally fruit copper density in Rhus WF-31 from Kanduyi in Bungoma had 1,639% more than that of the soil suggesting a high soil mining effect (Figure 3). Soil to fruit tissue correlations were, however, low and/or statistically not significant suggesting that the extent of uptake-ability is influenced by several factors rather than the total soil mineral content.

CONCLUSIONS

- The accessions' variation demonstrated higher Fe-Mn densities over those of Zn -Cu
- Rhus spp had the highest Fe-Mn > Grewa spp > Jackfruit > Ficus > Boabab spp depending on locations they were collected from. In that order, Ficus showed the highest iron-manganese but had the lowest Zn-Cu.

- High uptake-ability of elements in the tree species such as demonstrated by Rhus may be indicative of the soil-mining (a depletion effect) and/or fruit accumulation (a nutra-health plus) tendency.

ACKNOWLEDGEMENTS

We acknowledge the financial support from International Plant Genetic Resources Institute (IPGRI) to our student Ms Regina Munene Wanjiru for her M.Sc. field work that immensely contributed to this project. We are grateful to the technical support staff from the staff at the Institute of Nuclear Science and Technology laboratory at the University of Nairobi for all help and interest in this work. The direct interest by the Director of the Institute, David Maina, for assigning an agriculture bench at the Institute and even an office is gratefully appreciated.

Table 1a: Six analysis of variance (ANOVA) Tables (a to f) assessing soil element-induced accession tissue density differences

Source of variation in plant micronutrient density	df	MS Type III SS	F value	MEAN (ppm)	CV%
Tab1e (a) ANOVA among accessions on plant **K** criterion	22	154,451,960	16.7	19,823***	15.3
Tab1e (b) ANOVA among accessions on plant **Ca** criterion	22	16,979,384	32	5,014***	
Tab1e (c) ANOVA among accessions on plant **Fe** criterion	22	76,579	121.22	175***	111.2
Tab1e (d) ANOVA among accessions on plant **Mn** criterion	22	11,485	11.18	110***	10.3
Tab1e (e) ANOVA among accessions on plant **Zn** criterion	22	415	26.5	26***	24.3
Tab1e (f) ANOVA among accessions on plant on **Cu** criterion	24	13	3.31	9***	3.1

*** indicates statistical significant differences at probability $P_{< 0.0001}$.

Table 1b: Means Separation Using Duncan Test for Plant Micronutrient Density

a) Bungoma sites

Variation Picking Mineral Determinant Test (VPMD test)								**MINI-Cluster Rating**
		K	Ca	Fe	Mn	Zn	Cu	
Jackfruit- WF11	Chwele	24,267^{cd}	1,998^{gh}	64^{fg}	64^{ijk}	12^{ab}	10^{f}	6
Rhus- WF9		14,467^{ghi}	**7,777^{a}**	**238^{a}**	238^{c}	6^{e}	31^{cd}	8
Grewa- WF8		10,337^{i}	5,480^{cd}	97^{efg}	111^{ghi}	6^{e}	22^{e}	
Grewa- WF19	Nalondo	20,566^{def}	5,940^{c}	152^{bcde}	187de	11^{abcd}	37^{bc}	
Jfruit- WF21		20,000^{defg}	995^{h}	52^{g}	77^{hijk}	8^{cde}	13^{f}	3
Rhus- WF20		16,600^{efgh}	6,110^{c}	**268^{a}**	500^{b}	8^{cde}	34^{bcd}	8
Jfruit- WF32	Kanduyi	26,866^{bc}	2,460^{g}	80^{fg}	55^{jk}	9^{abcde}	14^{f}	4
Rhus- WF31		16,300^{fgh}	5,490^{cd}	172^{cb}	**561^{a}**	8.5^{bcde}	34^{bcd}	8
Grewa- WF30		9,793^{bc}	6,453^{cd}	116^{cdef}	229^{cd}	8^{cde}	29^{cd}	

b) Maseno area sites

Ficus- WF44	**Esivalu**	**34,500^{a}**	**8,137^{a}**	75^{fg}	67^{ijk}	**12^{ab}**	**42^{ab}**	**7**
Grewa- WF41	Esivalu	8,867^{i}	5,273^{cd}	103^{defg}	223^{cd}	8^{cde}	32^{cd}	
Ficus- WF62	Maseno	**32,400^{a}**	**8,137^{a}**	68^{fg}	88^{ghijk}	9^{abcde}	41^{ab}	8
Grewa- WF59	Maseno	17,767^{efg}	**8,590^{a}**	176^{b}	131^{fg}	7^{e}	32^{cd}	

Means within columns followed by same letters are not significantly different

Table 2: Means Separation Using Duncan Test for Soil contents at various sites

Fruit tree Accession	Site	K	Fe	Cu	Zn
Soil Mineral content at the Bungoma sites of the Grewa fruit tree accessions					
WF8-Grewa soil	Chwele	**14,300^{c}**	23,300^{ef}	10.1^{fgh}	37.4^{hij}
WF19-Grewa soil	Nalondo	6,995^{fg}	16,733^{ghi}	7.4^{fghijk}	29.7^{ijk}
WF30-Grewa soil	Kanduyi	**13,966.7^{c}**	11,700^{j}	8.8^{fghi}	39.7^{ghi}
Soil Mineral content at the Maseno sites of the Grewa fruit tree accessions					
WF41-Grewa soil	Esivalu	10,410^{d}	24,933^{ef}	15.5^{bcd}	51.5^{efg}
WF59-Grewa soil	Maseno	7,656.7^{efg}	**61,533^{a}**	16^{bc}	105^{ab}
Soil Mineral content at the Bungoma sites of the Rhus fruit tree accessions					
WF9-Rhus soil	Chwele	9,486.7^{de}	13,500^{hij}	8.4^{fghij}	42.7^{fgh}
WF20-Rhus soil	Nalondo	4,636.7^{hi}	16,600^{ghi}	10.9^{efg}	33.3^{hijk}
WF31-Rhus soil	Kanduyi	8,706.7^{def}	20,933^{fg}	2.1^{l}	27.7^{jk}
Soil Mineral content at the Maseno sites of the Rhus fruit tree accessions					
WF42-Rhus soil	Esivalu	6,486.7^{fgh}	18,233^{gh}	7.4^{fghijk}	78.9^{d}
WF60-Rhus soil	Maseno	18,533.8^{b}	39,000^{d}	6.7^{ghijk}	60.6^{e}
Soil Mineral content at the Bungoma sites of the Jack fruit tree accessions					
WF11-Jfruit soil	Chwele	14,566.7^{c}	25,500^{ef}	3.6^{kl}	53.2^{ef}
WF21-Jfruit soil	Nalondo	4,759.7^{hi}	17,300^{ghi}	5.31^{ijkl}	41.6^{fghi}
WF32- Jfruit soil	Kanduyi	7,770^{efg}	27,700^{e}	6.9^{fghijk}	44.7^{fgh}
Fruit tree accession	Site	K	Fe	**Cu**	Zn
Soil Mineral content at the Maseno sites of the Jack fruit tree accessions					
WF43-Jfruit soil	Esivalu	16,666.7^{b}	10,927^{g}	**23.17^{a}**	101.7^{ab}
WF61-Jfruit soil	Maseno	10,866.7^{d}	**51,333^{b}**	7.3^{fghijk}	95.1^{bc}
Soil Mineral content at the Maseno sites of the Ficus fruit tree accessions					
WF44-Ficus soil	**Esivalu**	**25,366.7^{a}**	47,767^{bc}	19.47^{ab}	86.43^{cd}
WF62-Ficus soil	Maseno	6,533.3^{fgh}	45,000^{c}	11.5^{def}	**112.3^{a}**
Soil Mineral content at the Bungoma sites of the Ficus fruit tree accessions					
WF10-Ficus soil	Chwele	10,140^{d}	2,133^{fg}	9.17^{fghi}	33.7^{hijk}
WF22-Ficus soil	Nalondo	7,673.3^{efg}	15,600^{hij}	11.3^{def}	34^{hijk}
WF33-Ficus soil	Kanduyi	6,390^{gh}	18,467^{gh}	6.9^{fghijk}	59^{e}
Soil Mineral content at the Kibwezi sites of the Jack fruit tree accessions					
WF67-Baobab	Kaseme	2,794.7^{i}	14,067^{hijj}	4^{jkl}	26^{jk}
WF71-Baobab	Masongaleni	3,590^{i}	20,967^{fg}	14.6^{cde}	42^{fgh}
WF76-Baobab	Lukenya	3,133.3^{i}	13,033^{ji}	5.8^{hijkl}	23.2^{k}

Means within columns followed by same letters are not significantly different

Table 3: Pearson r Correlation Coefficients between Fruit tissue and soil mineral concentrations

	Fruit tissue K	Fruit tissue Ca	Fruit tissue Mn	Fruit tissue Fe	Fruit tissue Cu	Fruit tissue Zn
Fruit tissue K		N.S	-0.034 0.004	-0.44 0.0001	0.55 <0.0001	N.S
Fruit tissue Ca			0.48 <0.0001	N.S	N.S	**0.72** **<0.0001**
Fruit tissue Mn				**0.66** **<0.0001**	-0.31 0.01	**0.72** **<0.0001**
Fruit tissue Fe						N.S
Soil K	N.S	0.28 0.01	N.S	0.27 0.02	N.S	0.30 0.01
Soil Ca	0.27 0.02	N.S	N.S	0.35 0.003	N.S	N.S
Soil Mn	N.S	0.24 0.04	N.S	N.S	N.S	N.S
Soil Fe	0.27 0.02	0.33 0.003	N.S	N.S	N.S	N.S
Soil Cu	N.S	N.S	N.S	N.S	N.S	0.27 0.02
Soil Zn	0.30 0.01	N.S	N.S	N.S	N.S	N.S

Table 4: Fruit Tissue Element Concentration as a % of Soil Mineral Content

Spp Accesion	Site	K % in fruit	Fe % in fruit	Zn % in fruit	Cu % in fruit
Ficus- WF44	Esivalu	136	0.16	14	216
Ficus- WF62	Maseno	**496**	0.15	8	357
Ficus- WF10	Chwele	308	5.4	33	**491**
Ficus- WF22	Nalondo	244	0.6	26	239
Ficus- WF33	Kanduyi	293	0.3	15	447
Rhus- WF9	Chwele	152	1.8	14	369
Rhus- WF20	Nalondo	358	1.6	24	311
Rhus- WF31	Kanduyi	187	0.8	31	**1,659**
Rhus- WF42	Esivalu	179	0.9	11	**485**
Rhus- WF60	Maseno	64	0.4	12	**433**
Grewa- WF8	Chwele	72	0.4	16	219
Grewa- WF19	Nalondo	294	0.9	37	500
Grewa- WF30	Kanduyi	70	1.0	20	328
Grewa- WF41	Esivalu	85	0.4	16	207
Grewa- WF59	Maseno	232	0.3	7	200
Jackfruit- WF11	Chwele	167	0.3	23	278
Jackfruit- WF21	Nalondo	**420**	0.3	19	245
Jackfruit- WF32	Kanduyi	346	0.3	20	202
Jackfruit- WF43	Esivalu	161	0.7	12	60
Jackfruit- WF61	Maseno	207	0.1	13	138

REFERENCES

1 **Maundu PM, Ngungi GW and CHS Kabaye** Traditional food plants of Kenya. Kenya Centre for Indigenous Knowledge (KENRIK). National Museums of Kenya, Nairobi, Kenya. 1999.

2 **Gackowski J , Mbazo J, Mbah G and T Moulende** African traditional fruit tissue vegetables and the urban and peri-urban poor. *Food Policy* 2003; **28:** 221-23.

3 **Johns T and B Sthapit** Bio-cultural diversity in the sustainability of developing
country food systems. *Food and Nutrition Bulletin* 2004; **25:** 143-155.

4 **Johns T** Plant Bio-diversity and malnutrition: Simple solutions to complex problems: Theoretical Basis for the Development and Implementation of a Global Strategy Linking Plant Genetic Resource Conservation and Human Nutrition. *African Journal of Food, Agriculture, Nutrition and Development.* 2003; **3(1).**

5 **Gebauer J, El-Siddig K, El Tahir BA, Salih AA, Ebert G and K Hammer** Exploiting the potential of indigenous fruit trees: Grewia tenax (Forssk.) Fiori in Sudan. *Genetic Resources and Crop Evolution.* 2007: **54:** 1701 – 1708.

6 **Khemiss F, Ghoul-Mazgar S , Moshtaghi AA and D Saidane** Study of the effect of aqueous extract of Grewia tenax fruit on iron absorption by everted gut sac. *J. Ethnopharmacol.* 2006; **103:** 90-8.

7 **Acedo AL** Multipurpose Tree Species Network Series: Jackfruit biology, production, use, and Philippine research. Forestry/Fuelwood Research and Development Project. The Phillipines. 1992.

8 **Craig RE and HI Manner** Species Profiles for Pacific Island Agroforestry www.traditionaltree.org, April 2006.

9 **Wickens GE** The uses of the baobab (adansonia digitata l.) in Africa. **In:** Browse in Africa. Paper presented at the International Symposium on Browse in Africa, Addis Ababa, April 8 – 12, 1980, International Livestock Center for Africa, ILCA.

10 **National Research Council.** Lost Crops of Africa. Vol 3: Fruits, Washington, D.C.: The National Academies Press, 2008.

11 **Yazzie D, Van Derjagt DJ, Pastuszyna A, Okolo A and RH Glew** The amino acid and mineral content of baobab (Adansonia digitata L.) leaves. *Journal of Food Composition and Analysis.* 1994; **7:** 189 – 193.

12 **Jaetzold R and H Schimdt** Farm Management Handbook of Kenya (Vol. II, Part A) Natural Conditions and Farm Management Information, West Kenya (Nyanza and Western Provinces). Nairobi: Ministry of Agriculture. 1982.

13 **Jaetzold R and H Schimdt** Farm Management Handbook of Kenya (Vol. II, Part C) Natural Conditions and Farm Management Information, East Kenya (Eastern and Coast Provinces). Nairobi: Ministry of Agriculture. 1982.

14 **Cooper DR and PS Schindler** Instruments for participant communication. **In:** Sources and collection of Data pp 354. Business Research Methods. Tata McGraw-Hill Publishing Co. New Delhi. 2005: 354.