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Mineral Macro-Nutrients, Micro-Nutrients and Other Elements in Leaves of Malunggay Plant (*Moringa Oleifera*) Sampled in Some Locations in the Philippines

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Significance

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Malunggay or Moringa plant, with binomial or scientific name Moringa oleifera is widely known in the country as malunggay vegetable/plant. In many countries also known as: "horse radish tree"; "drumstick tree"; and "Ben oil tree" attributed to its: horseradish leaf taste; long, slender, triangular seed pods; oil derived from the seeds, respectively (Wikipedia 2009). It's a perennial softwood, low-quality timber tree now extensively grown in semi-arid, tropical and subtropical countries. Most of its plant parts exhibit nutritional, therapeutic, and prophylactic properties (Fahey 2005, Tree for Life Journal; Wikipedia 2009, the free encyclopedia; Malunggay Philippines, Manila Bulletin; Mamaril 2009, in BIOLIFE).

It has become an important crop in India, Ethiopia, the Philippines, and Sudan, and now being grown in west, east and south Africa, tropical Asia, latin America, the Caribbean, Florida and the Pacific Islands (Fahey 2005). Almost all parts of the malunggay tree are edible and medicinal, have long been consumed by humans as early as ancient Roman and Greek times. The many food and non-food uses of the tree are presented in the table below.

Table 1. The various food and non-food uses or applications of the "Miracle Tree": Moringa (Malunggay) Crop (Fuglie 1990 cited by Fahey 2005).

Food / Nutritional / Medicinal Uses	**Non-Food, Industrial and Environmental Uses**
1. Antimicrobial/biocidal (all plant parts), against bacteria, virus, fungi, parasites	1. Domestic cleaning agent (crushed leaves)
2. Honey (flower nectar)	2. Blue dye (wood)
3. Ben oil (seed, yield 30-40% oil), sweet non-sticking, non-drying	3. Fencing (living trees)
4. Salad oil	4. Biogas (leaves)
5. Green, roasted, powdered seeds (for tea and curries)	5. Animal forage (leaves and treated seedcake
6. Nutritional : anti-oxidant, highly digestable protein, carotenoids, energy, vitamins and minerals 7. Circulatory/endocrine disorders	6. Fertilizer (seed-cake)
8. Digestive disorders 9. Inflammation	7. Foliar nutrient (extracted from leaves)
10. Immunity	8. Honey and sugar-clarifier (powdered seeds)
11. Nervous disorders	9. Green manure (leaves)
12. Reproductive health	10. Fine machine lubrication (seed oil)
13. Skin disorders	11. Perfume and hair care products
14. Cancer therapy/protection	12. Flocculation of contaminants and purification of water (powdered seeds)

In the Philippines. Moringa is commonly grown in home gardens and also as living fences, largely for its leaves used as vegetable component in soups and as well as in meat and fish dishes. A popular Filipino dish is "tinolang manok" in which green Moringa leaves and slices of green papaya (*Carica papaya*) fruit are essential ingredients. Thus, in the country, small and big rural and urban markets daily sell Moringa leaf bunches (*dahon ng malunggay* in Tagalog or *dahon sa kamunggay in Cebuano*).

Moringa had been recognized as a practical and highly nutritional food source in the tropics because the tree is in full leaf at the end of the dry season when other food sources are scarce. Recently, many workers had mentioned a large number of reports on the nutritional qualities of Moringa in both scientific and the popular literatures. The Trees for Life Organization (2005) mentioned that ounce-for-ounce, Moringa leaves contain more Vitamin C than carrots, more calcium than milk, more iron than spinach, more vitamin C than oranges and more potassium than bananas, and that the protein quality of Moringa leaves rivals that of milk and eggs.

From the report of Dr Vivencio Mamaril (2009), a member of the DA-Bureau of Plant Industry Biotech Core Team, it was clear that dried malunggay leaves has 2.5 to 4 times higher values in most nutritional food content than fresh leaves. Dried leaves, i.e., 295 calories; 27.1 g protein; 2.3 g fat; 38.2 g CHOs; 19.2 g fiber, 2003 mg Ca and 28.2 g Fe, while fresh leaves with: 92 calories; 6.7 g protein; 1.7 g fat, 13.4 g CHOs, 0.9 g fiber; 440 mg Ca and 7 mg Fe. The weight or volume of material consumed was not mentioned, nevertheless, it could be per 100 g (?).

As to phytochemicals inherently produced by Moringa species, Fahey (2005) cited that this plant family was found to be rich in compounds containing the simple sugar, rhamnose, and it is high in a fairly unique group of compounds called glucosinolates and isothiocyanates, including a number of vitamins and minerals, as well as carotenoids phytochemicals.

Even if the malunggay tree is a sun- and heat-loving plant, it can be grown as a single crop as well as an intercrop or companion crop like coconut, and other crops (cereals, tubers, vegetables fruit and industrial tree crops). In the case of coconut palms, Malunggay plant should be grown the right developmental stage of coconut (field-planting to 7 years or at 25 years and older (Magat 2008) and should sunglight becomes a limiting factor the PCA's coconut leaf pruning technique may be adopted (Magat et al 1999).

To optimize the utilization of the leaves of malunggay for nutritional and medicinal purposes, it is necessary to determine the mineral nutrient contents, both macronutrients (N, P,K, Ca, Mg, Na, Cl, S) and micronutrients (B, Zn, Fe, Mn, Cu and Mo). Also important is an understanding of the other elements which are either beneficial or toxic [at high concentrations as heavy metals (Cd, Pb, Hg, Ni, Cr As)]. Hence, these will presented in the ensuing sections. The main leaves (leaf blades) and its leaf stalks are analyzed separately to provide us a good understanding of the concentration of nutrients and other elements in these two components. Usually, the leaf stalks are thrown away as wastes. It should interesting to know how much still are the contents of each mineral nutrient or element in the leaf stalk.

A. MINERAL NUTRIENT CONTENTS IN MALUNGGAY LEAVES

In this Technology Notes-Advisory, the contents or concentration of nutrients or elements are all expressed in dry matter basis, that is, as percent (%) for macronutrients which are in high content and parts per million (ppm = mg/kg) for micronutrients and the other elements reported. For easy comparison, take note that 1% = 10,000 ppm; 0.1% = 1,000 ppm; 0.01% = 100 ppm; 0.001% = 10 ppm). In this Notes-Advisory, we are concern with the mineral elements of only two parts of the malunggay plant: 1) the leaves or leaf blades; and 2) the stalk or leaf stalk. The malunggay stalks are the small leaf branches in which the leaves are directly attached. When leaves are utilized, the leaves are separated from the stalks which are usually thrown away or considered tree wastes.

1. Leaf Blades (Table 2, Figures 1.1 & 2.1)

In leaf blade macronutrients, the mean (average of 4 locations) concentration falls in the order (highest to lowest): **N** (4.74%) > **Ca** (2.21%) > **K** (1.80%) > **S** (1.36%) > **Mg** (0.45%) > **P** (0.33%) > **Cl** (0.20%) > **Na** (0.06%).

While in leaf micronutrients, the decreasing order: **Fe** (100 ppm) > **B** (50 ppm) > **Mn** (34 ppm) > **Zn** (24 ppm) > **Cu** (5 ppm).

The average levels of heavy metals as As,Cd,Cr,Ni are less than 1 ppm or 1 mg/kg and mostly not detectable (ND) in the coastal area sampled (PCA-ZRC, San Ramon, Zamboanga City). The level of leaf Pb range from ND to 91 ppm (Anos, Los Banos, Laguna). The normal range Pb in plants is 1-20 ppm. Usually, inorganic Pb from petrol combustion is higher (50 ppm or more) in plant leaves of areas 150 m from the busy

roads (Pb added to petrol as tetra ethyl lead). On the other hand the mean content of other beneficial elements: 3.4 ppm Mo, 1.4 ppm Se and 0.25 ppm Co.

Macro-nutrientwise, the highest leaf blade N (5.57%) was in PCA-ARC (Guinobatan, Albay); leaf P (0.41%) - PCA-ZRC, San Ramon, Zamboanga City; leaf K (2.21%) - PCA-ZRC, leaf Ca (2.45%) - PCA,ZRC, leaf Mg (0.56%) - PCA-ZRC, leaf Na (0.24%) - PCA-ZRC, leaf Cl (0.24%) - PCA-ZRC); and leaf S(1.85%) - PCA-DRC, Bago-Oshiro, Davao City.

While, for leaf micronutrient, the highest leaf B (60 ppm) was found in Los Banos, Laguna; leaf Fe (129 ppm, PCA-DRC); leaf Mn (98 ppm, PCA-DRC); leaf Cu (6 ppm, PCA-ARC and PCA-DRC); and leaf Zn (42 ppm, PCA-ZRC).

In general, the leaf blade nutrient concentrations are very likely influenced by the inherent soil chemistry or soil nutrient levels, particularly that of N, K, Ca, Mg, S, including micronutrients and other elements/or heavy metals. However, leaf P, Na and Cl strongly appears genetically controlled by the malunggay tree, considering the very narrow range of: 0.251 – 0.414%; 0.038 – 0.081 ppm Na; and 0.127 – 0.236 ppm Cl.

2. Leaf Stalks (Table 2 and Figures 1.2 & 2.2)

As in leaf blades, in this Technology-Advisory Notes, the nutrient concentrations in leaf stalks are also all based on the dry matter.

In leaf stalks, the mean concentration of macronutrients (from 4 locations) is in the order (highest to lowest): **K** (2.29%) >**N** (1.85%) > **Ca** (1.19%) > **Cl** (0.65%) > S (0.45%) > Mg (0.23%) > 0.20% > Na (0.07%).

While in stalk micronutrients, the decreasing order: **Fe** (44 ppm) > B (**17** ppm) > **Zn** (11 ppm) > Mn (10 ppm) > Cu (4 ppm). Beneficial elements Se, Mo and Co have a stalk mean of 1.4, 1.6 and 0.10 ppm, respesctively. On the other hand, heavy metals As and Cd are both less than 0.5 ppm, while mean levels of Ni and Pb are quite high 16 and 32 ppm, respectively. But in leaf stalk and leaf blades of Malunggay from PCA-ZRC, levels of heavy metals and other elements are very low to not detectable (ND), meaning, concentration of these are extremely low.

Macro-nutrientwise, the highest malunggay stalk N (2.48%) was in PCA-ZRC, San Ramon, Zamboanga City); stalk P (PCA-ZRC);stalk K (2.48%) in Los Banos, Laguna; stalk Ca (1.48%) in Los Banos, Laguna; stalk Mg (0.38%) in PCA-DRC, Ba-Oshiro, Davao City), stalk Na (0.10% in Los Banos, Laguna); stalk Cl (0.97% in Los Banos. Laguna) and stalk S (0.54%) in PCA-DRC, Davao City.

And for the leaf stalk micronutrients, the highest content in B (21 ppm) was in PCA-ARC, Guinobatan, Albay; stalk Fe (67 ppm) in PCA-DRC, Davao City; stalk Mn (31 ppm) in PCA-DRC; stalk Cu (5.3 ppm in PCA-ZRC, Zamboanga City; stalk Zn (15.4 ppm) also in PCA-DRC.

As in leaf blades, the leaf stalk nutrient concentrations are clearly influenced by the soil chemistry or soil nutrient conditions of the sampled areas, particularly in stalk N, K, Ca, Mg, Cl and S, including all micronutrients and other elements. However, it appears that both stalk P and Na are genetically controlled by the malunggay plant, as indicated by almost similar content of each nutrient in all sampled areas.

Table 2. Summary of macro-and micro-nutrients and other chemical elements in leaf and stalk of Malunggay plant (Moringa oleifera), sampled from 4 locations in the Philippines (analylzed by the PCA Plant and Soil Analysis Division, PlantTissue Analysis Laboratory, Diliman, Quezon City, Metro Manila (2009).

Element / Analyte, Total (oven dry basis)	PTAL Lab Code # / Sample Information									
	P-189.08 / Leaf-LBL[a]	P-247.08 / Leaf-ARC[b]	P-249.08 / Leaf -DRC[c]	P-141.09 / Leaf - ZRC[d]	Mean (Leaf)	P-190.08 / Stalk-LBL[a]	P-248.08 / Stalk -ARC[b]	P-250.08/ Stalk -DRC[c]	P-142.09 / Stalk - ZRC[d]	Mean (Stalk)
(%)										
N (nitrogen)	4.470	5.573	5.033	3.871	4.737	1.905	1.456	1.456	2.600	1.854
P (phosporus)	0.293	0.376	0.251	0.414	0.334	0.217	0.176	0.142	0.255	0.198
K (potassium)	2.047	1.792	1.129	2.212	1.795	2.480	2.316	2.125	2.249	2.293
Ca (calcium)	2.178	1.818	2.391	2.458	2.211	1.485	1.113	1.321	0.846	1.191
Mg (magnesium)	0.312	0.355	0.556	0.561	0.446	0.151	0.185	0.380	0.191	0.227
Na (sodium)	0.081	0.068	0.038	0.052	0.060	0.104	0.069	0.068	0.053	0.074
Cl (chloride)	0.232	0.127	0.197	0.236	0.198	0.967	0.519	0.772	0.361	0.655
S (sulphur)	0.983	0.922	1.852	1.689	1.362	0.399	0.437	0.535	0.448	0.455
(mg-kg^{-1})										
B (boron)	59.7	55.3	41.6	44.4	50.2	16.2	21.3	15.4	15.2	17.0
Fe (iron)	88.4	103.1	128.4	80.2	100.0	66.7	37.4	67.4	2.8	43.6
Mn (manganese)	18.6	18.4	98.4	1.1	34.1	5.1	5.8	31.1	0.377	10.6
Cu (copper)	5.3	6.2	6.2	2.8	5.1	3.1	3.1	3.4	5.3	3.7
Zn (zinc)	15.8	21.2	16.9	41.8	24.0	15.1	11.7	15.4	2.8	11.2
Al (aluminium)	39.9	44.5	82.8	<LLD*(0.094)	55.7	28.3	46.0	60.3	<LLD*(0.094)	44.9
As (arsenic)	(ND**	ND**	ND**	0.263	0.263	ND**	ND**	ND**	0.213	0.213
Cd (cadmium)	0.418	<LLD*(0.090)	<LLD*(0.090)	<LLD*(0.090)	0.418	0.042	<LLD*(0.090)	<LLD*(0.090)	<LLD*(0.090)	0.042
Cr (chronium)	0.078	0.100	0.200	<LLD*(0.092)	0.126	5.1	0.028	0.274	<LLD*(0.092)	1.8
Ni (nickel)	ND	0.015	0.363	0.236	0.205	<LLD*(0.924)	0.100	31.1	<LLD*(0.924)	15.6
Pb (lead)	91.6	6.1	10.2	<LLD*(0.004)	36.0	85.0	5.1	6.0	<LLD*(0.004)	32.0
Se (selenium)	0.343	1.2	4.0	<LLD*(0.027)	1.8	1.4	0.634	2.2	<LLD*(0.027)	1.4
Mo (molybdenum)	4.6	3.0	1.0	1.576	2.5	3.4	2.3	0.529	0.216	1.6
Co (cobalt)	0.170	0.119	ND**	0.473	0.254	0.047	0.022	ND**	0.240	0.103

[a] S.S.Magat place, Los Banos, Laguna (inland-upland) [b] PCA- Albay Albay Res. Center (inland-upland) [c] PCA-Davao Res. Center (inland-upland) [d] PCA-Zamboanga Res. Center (coastal-flat)
*LLD – Lower Limit of Detection **ND- Not Detectable *** NA – Not Applicable

Figure 1. Macro-Nutrients in Leaf and Stalk of Malunggay Plant

(Moringa oleifera) Sampled from Four Locations in the Philippines analyzed by the PCA-Plant and Soil Analysis Division, Diliman, Quezon City (2009)

Figure 1.1. MALUNGGAY LEAF (%, dry matter)

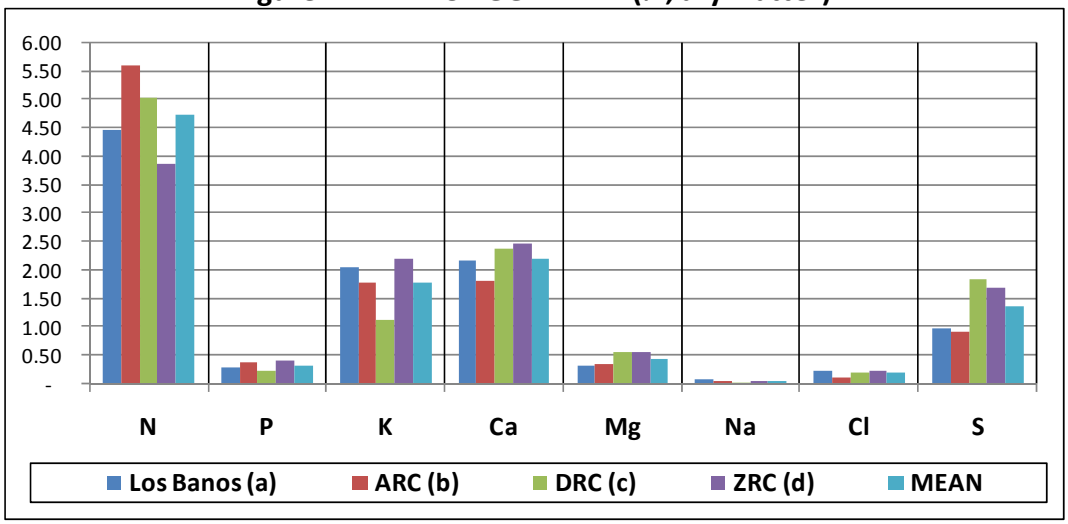
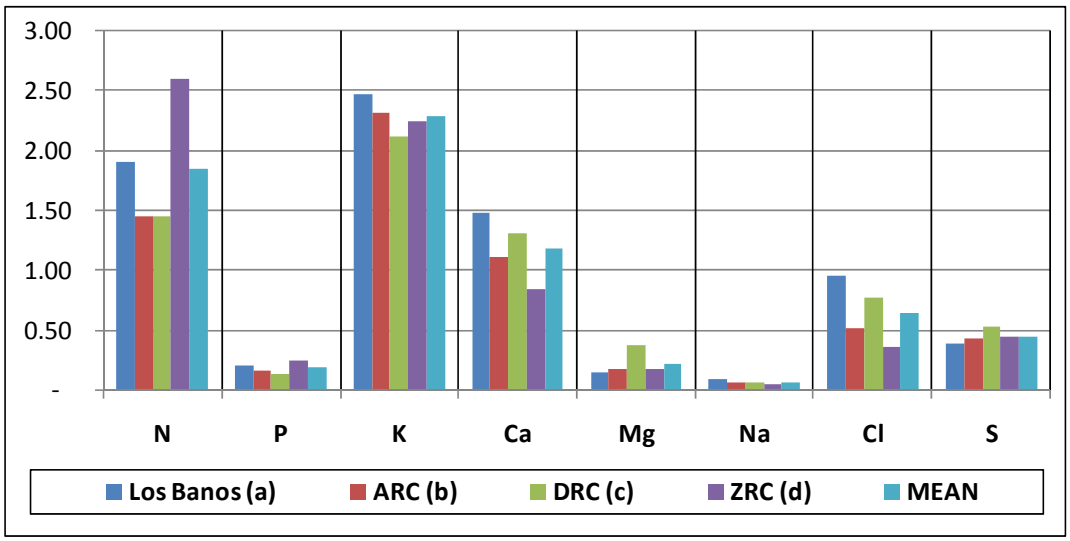


Figure 1.2. MALUNGGAY STALK (%, dry matter)



(a) S.S.Magat place, Los Banos, Laguna (inland-upland)
(b) PCA- Albay Albay Res. Center (inland-upland)
(c) PCA-Davao Res. Center (inland-upland)
(d) PCA-Zamboanga Res. Center (coastal-flat)

B. Quantity of Nutrients in Malunggay Leaves

From Table 2 and Figures 1 and 2, we can determine the quantities of macronutrients and micronutrients. Using a reference weight, say for each 10 kg of dried malunggay leaves, Table 3 indicates weight of each nutrient supplied or found per 10 kg and 100 kg of malunggay leaves, in leaf blades and leaf stalks.

Among the macronutrients, Table 3 shows that the highest quantity in the malunggay leaf is N, followed by Ca, K, Mg, P, Cl and Na. While in the case of micronutrients, the highest is Fe, followed by B, Mn, Zn and Cu. In the stalks, K nutrient is the highest, followed by Ca, N, Cl, S, Mg, P and Na.

The nutrient ratio of leaf and stalk (NRLS) in malunggay plant apparently shows that: 1) higher amounts in the leaf blades of nutrients N, Ca, S, P, Mg and S (NRLS >1) and lower nutrient amounts in the leaf of K,Na and Cl; 2) Structural nutrients stay more in the leaf tissues while the non-structural and circulating nutrients are concentrated more in the leaf stalks 2) All micronutrients (Fe, B, Mn, Zn and Cu) are higher in the leaves over the stalks (NRLS > 1 (3.4–1.4).

Table 3. Estimated quantity of macronutrients and micronutrients (per 10 kg and 100 kg dry weight basis) of Malunggay leaves based from the mean values of 4 sampled locations in the Philippines (2009).

Nutrients	**Leaf**		**Stalk**		**Leaf/Stalk**
Macronutrient	**g/10kg**	**Kg/100 kg**	**g/10 kg**	**kg/100 kg**	**Nutrient Ratio**
N	473	4.73	185	1.85	2.5
Ca	221	2.21	191	1.91	1.2
K	179	1.79	293	2.93	0.6
S	136	1.36	45	0.45	3.0
Mg	45	0.45	23	0.23	1.9
P	33	0.33	19	0.20	1.7
Cl	19	0.20	65	0.65	0.3
Na	6	0.06	7	0.07	0.9
Micronutrient	**mg/10 kg**	**g/100 kg**	**mg/10 kg**	**g/100 kg**	**Nutrient Ratio**
Fe	1000	100	436	44	2.3
B	500	50	170	17	3.0
Mn	340	34	100	10	3.4
Zn	240	24	112	11	2.1
Cu	50	5	37	3.7	1.4

Figure 2. Micro-Nutrients in Leaf and Stalk of Malunggay Plant

(Moringa oleifera) Sampled from Four Locations in the Philippines analyzed by the PCA-Plant and Soil Analysis Division, Diliman, Quezon City (2009)

Figure 2.1. MALUNGGAY LEAF (ppm or mg/kg, dry matter)

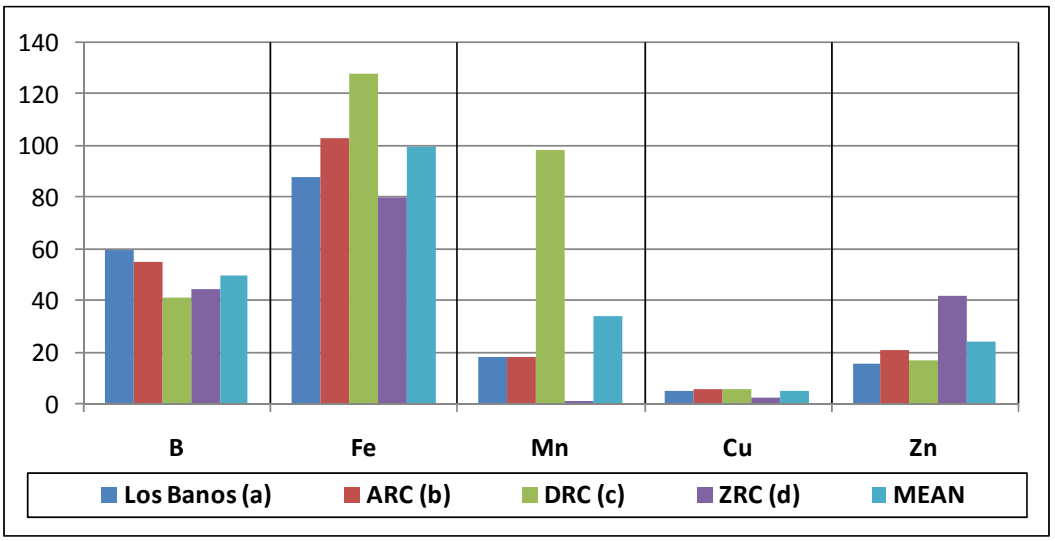
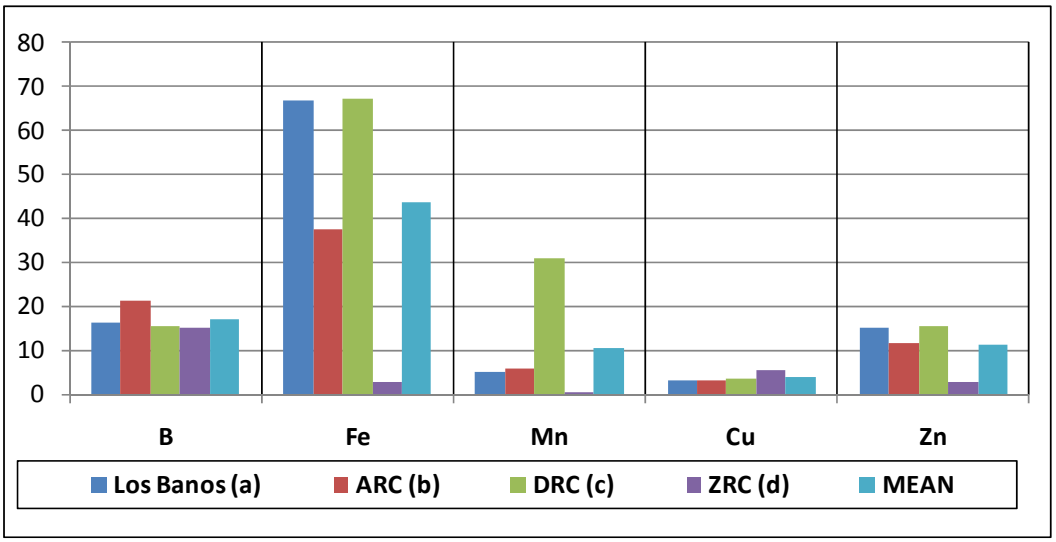


Figure 2.2. MALUNGGAY STALK (ppm or mg/kg, dry matter)



(a) S.S.Magat place, Los Banos, Laguna (inland-upland)
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(d) PCA-Zamboanga Res. Center (coastal-flat)

C. Concluding Notes

Among many other concerns, this presentation aims to provide information searchers and technology users of more updated data and information on the elemental and nutrient contents of Moringa or Malunggay plant, particularly, on its leaves used largely for vegetable, nutritional and medicinal purposes in the country and many countries, worldwide. To some extent, this initiative confirmed and strengthened the earlier reports on the high leaf nutrient content of the plant, particularly Fe, Ca, K, S and N. Many elements such as Fe, Mn, Cu, B and Zn are essential at low concentrations but are toxic at higher or excessive levels.

Range of macro- and micronutrient (mineral elements) contents distributed in Malunggay leaf and stalk, including other beneficial and heavy metal elements represented by the four different locations (Los Banos, Laguna; Guinobatan, Albay; Bago-Ohiro, Davao City and San Ramon, Zamboanga City) under field conditions could enhance our understanding of capability of the plant to supply food, nutritional and medicinal benefits to developing countries where food security is seriously threatened nowadays and years ahead.

As the soil is a major source of heavy metals, we should be aware of the critical contents or considered limit on safe crop production (Mengel and Kirby 1987): Zn – 300 ppm; Cu – 100 ppm; Cr – 100 ppm; Pb – 100 ppm; Ni – 50 ppm; Cd – 3 ppm and Hg – 2 ppm. While in plants, the critical levels presented (Sauerbeck 1982) for heavy metals are: Zn (150-200 ppm); Cu (15-20 ppm); Cr (1-2 ppm); Cd (5-10 ppm); Pb (10-20 ppm); Hg (2-5 ppm); Ni (20-30 ppm) and Co (20-30 ppm). Higher contents than these are very likely toxic.

*Finally, may we be reminded that before we throw away or wastes the leaf stalk separated from the leaf blades of Malunggay, let's consider that this plant stalk still contains substantial amounts of valuable macro- and micro-nutrients for social and economic benefits to many, if not all***.**

Acknowledgement

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