Mineral Analysis of Moringa oleifera: Electrolyte Interactions

By Donald D. Job, Ph.D.

BACKGROUND

Moringa oleifera (also known as the Drumstick tree) is a well known plant in sub-tropical and tropical climates. Also known as a "miracle tree" it has been credited with many healing properties as well as providing other practical uses (such as in purifying water) [Witt, 2013; Price, 1985; Aslam, 2005]. As a source of nutrients, the leaves are dried and made into a tea. A tea or "meal" can also be made from seeds. Given the extent of malnutrition in the world and the resilience of the Moringa tree to provide a broad range of important nutrients, there is a need to better understand the biology of this plant and its potential for use by individual families as well as for commercial production. There are numerous biochemicals in the Moringa plants such as antioxidants, vitamins and proteins that could provide health benefits; but well controlled clinical studies are sparse [Aslam, 2005]. The alleged health benefits of Moringa extracts may be the result of the presence of yet to be identified novel compounds which is another reason for undertaking the present study.

Recently investigators have studied the genome of Moringa to identify genes that may contribute to the plant's novel characteristics of high protein content, fast-growth, heat and stress tolerance [Yang Tian , 2005]. It has been suggested that this understanding of the genome could lead to the development of improved versions of more conventional food crops like corn and soybeans. Along with such a study is a consideration for improving the nutrient profile although thus far the research has not identified genes that are involved for example in mineral metabolism.

Given the foregoing, one of our research goals was to determine the feasibility of growing Moringa in a more temperate climate (North Carolina) and to harvest the leaves and seeds for potential use for health improvement (Job, 2018b) It is further our research goal to determine whether the mineral profile of the leaves compares favorably to two other common sources of food; namely corn meal and soybean meal. The results of that study are reported in another paper [Job, 2018a]. It compares Moringa mineral profiles with comparable profiles from corn and soybeans given by Batal [Batal, et al. 2010].

There have been other studies of the nutrients found in Moringa (see for example references of Witt, 2013; Price, 1985 and Aslam, 2005). There have been fewer studies making direct comparisons with other food sources. Furthermore, most of the studies have been carried out on plants grown in the wild. To our knowledge, this is the first study in which a complete mineral profile has been done on plants grown under controlled conditions in the temperate climate of southern United States (North Carolina at latitude/longitude in Decimal degrees format 35.400351, -79.111720) and for which additional biological factors have been determined.

The emphasis of the present research paper is on the role of various minerals in growth, on their transport and utilization under varying conditions and stresses and to examine some interactions or correlations between minerals.

METHODS

The Moringa oleifera plants were grown from seeds provided by ECHO, a global initiative promoting sustainable food production throughout the world (17391 Durrance Road, North Fort Myers, FL 33917 USA www.ECHOcommunity.org). Tissue samples were taken from plants grown between Spring and Fall of 2016 and again in 2017 after a winter dormancy period in central North Carolina.

In the first year Moringa seeds were started in early Spring (April 30, 2016) in a large pot (ca. 14" diameter at the top) that had been filled with different layers of material. The bottom layer was 1.5 inches of rocks, the next 2 inches was soil with high clay content. The next layer was 4 inches of a mixture of peat moss and a commercial "garden soil." The top 2 inches was a commerical potting soil (Miracle Gro Potting Mix 0.21-0.11-0.16). See Table of composition in the Appendix. Seeds were initially soaked in water for three (3) days. Following this, five (5) seeds were placed about 1.0 to 1.5" down into the top layer that had been pre-moistened. Moisture and temperatures were monitored daily using a moisture meter and a min/max thermometer respectively.

Plants were watered and fertilized using a Miracle-Gro water soluble Plant Food formulation 24-8-16 (1 Tablespoon/gallon) which in some instances was supplemented by a solution enriched by magnesium sulfate at a concentration of 1 teaspoon per gallon of Epsom salts (hydrated magnesium sulfate). The Miracle Gro Potting Soil formulation (N-P-K) also included the minerals B, Cu, Fe, Mn, Mo, Zn. However, it does not contain Magnesium, Calcium nor Sulfur as seen in the composition table in the Appendix. The water source (other than natural rain) was from the City of Sanford which draws its water from the Cape Fear River and two deep wells. An analysis of that water is provided in the Appendix.

Mineral analysis was performed by the NCDA & CS Agronomic Division of NC State University in Raleigh, NC. The method for analysis of mineral is a variation of the US Environmental Protection Agency. 1994. Method 200.7 "Determination of metals and trace elements in water and wastes by inductively coupled plasma-atomic emission spectrometry." [US EPA, 1994]

The NCDA&CS tissue analysis measures crop levels of up to 13 essential nutrients required for normal plant growth and development. Primary nutrients (N, P, K) are needed in greatest quantities, secondary nutrients (Ca, Mg, S) in lesser quantities, and micronutrients (Fe, Mn, Zn, Cu, B, Mo, Cl) in very small amounts. Concentrations of primary and secondary nutrients and Cl are measured as a percentage and other micronutrients in parts per million (ppm), all on a dry-weight basis. Resulting data appears in the following section.

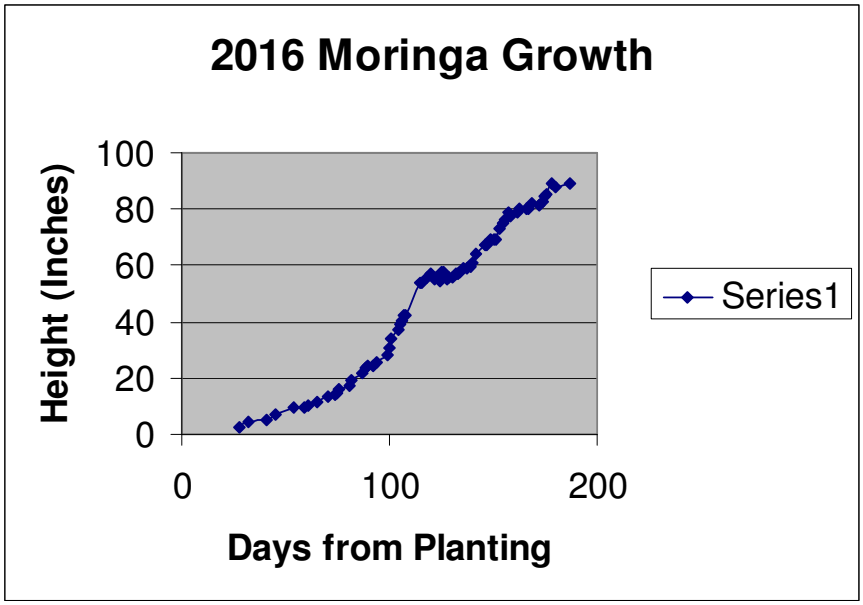
A soil analysis was made toward the end of the first year of the old soil and the new soil after transplanting into a larger pot. The older soil had a pH of 5.8 and a high Phosphate Index (116), a slightly elevated Potassium Index. The NC Agricultural Service recommended additional nitrogen. The top layer of soil in the new pot after transplanting the tree had a pH of 4.9, a very high Phosphate Index (212) and a very high Potassium Index (419). They recommended Nitrogen and lime additions. The new "topsoil" (top 2 inches) was mostly all Miracle Gro Potting Soil which in retrospect may have not been the best choice since it was higher in phosphorous and potassium than one would normally encounter.

RESULTS

Growing Considerations

Germination usually took 2-3 weeks as indicated in the growth curve seen in Figure 1.

Figure 1
Moringa Growth Season 1



From PlantGrowthData / Plot 2 - April 27, 2016 to November 19, 2016 - (207 days later).

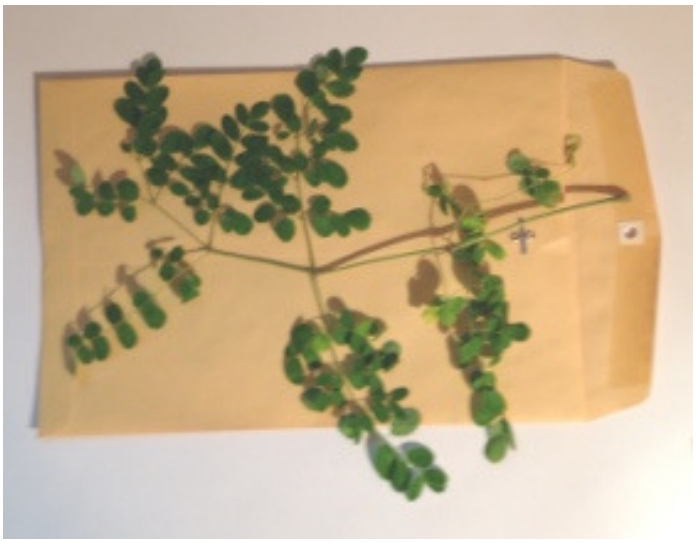
The appearance of the plant after 125 days is seen in Figure 2.

Figure 2
Moringa after 125 Days

At various times throughout the growing season, some branches were removed for mineral analysis. At 180 days the plant was transplanted to a larger container.

Figure 3 shows a typical branch size that was removed. The envelope was 10 inches wide by 15 inches long. Smaller clusters of leaves were removed, placed in a pre-weighed brown paper bag. The sample size used for analysis ranged from 1 to 6 grams fresh weight of leaves. The stems were discarded.

Figure 3
Typical Branch Taken for Analysis



Many branches were removed for analysis in November when temperatures fell into the 30's (F.) and below freezing. The top portion of the plant was cut back and the container was placed in a darkened cellar space for the winter months of December through March. The plant had previously been replanted into a larger container. In March, 2017 the container was brought back out into the open and some new shoots grew from the old main stalk. After a few months these new branches became fully developed as noted in Figure 4.

Figure 4 Second year Growth

The photo in Figure 4 was taken August 31, 2017 at which time the height of the new branches exceeded 109 inches. The yard sticks are shown end-to-end against the white backdrop. Some branches were removed for tissue analysis during this period.

Towards the end of the second growing season (October 18, 2017) the height had reached 129.5 inches and multiple side branches had developed. Throughout this period some of the smaller

sections were taken for leaf mineral analysis at different periods and under different conditions. Other branches were removed and dried for use as a tea.

Figure 5 is a photo taken on October 27, 2017. During this period temperatures were still in the 40-60 degree range. Drooping (loss of turgor) of the upper branchlets was noted periodically but resolved after providing 2-3 liters of water. However, as temperatures continued to fall beginning in November, some droopiness (wilting) set in that was not resolved by watering or fertilization (liquid fertilizer). Overnight temperatures reached freezing a number of times in November while daytime highs rose to the mid-60's (F.).

Figure 5
Growth Near End of Season 2

Water Transport Considerations

The Moringa plant is known to grow in arid and semi-arid conditions and is tolerant of low moisture. It is also reported that over-watering can be deleterious [ref]. Our experience early in

the season was that the plant system required 1-3 liters per day depending upon the temperature and humidity. If less than this was provided (either by natural rainfall or by adding water to the container from the top) temporary wilting of the outer branches could occur. When wilting (loss of turgor) occurred, adding 2 liter of water corrected the problem within about two to three (2-3) hours. In fact we conducted some tests and did an analysis of both the time period and volume transport rates. An initial experiment was conducted on 9/24/2016. It was noted at 10:15 am the top portion of the plant had wilted overnight. It was estimated that the volume of leaves effected was about 100 ml. Recovery efforts were begun by adding 1 liter of water to the container. At 12:15 pm, 500 ml of a commercial bottled water (Nestle water with minerals) was added. By 1:15 pm, total restoration of turgor was noted. Pictures were taken to document the steps to recovery.

What can be inferred about the transport rate? The top of the plant is 69 inches from the top of soil and the pot height for soil is approximately 10 inches. So, for estimation purposes consider a transport distance of 72 inches or 6 feet. Furthermore, although 1.5 liter of liquid was added, not all went to the top of the plant; but probably at least 100 ml did over the period of less than 3 hours (in order for recovery to occur).

Thus, a conservative estimate of the rate of travel was at least:

72 inches / 3 hours = 182 cm /180 minutes ➔ 1 cm / min

And, the volume transfer rate is:

100 ml/3 hour = 33 ml/hour OR 100 ml/180 minutes = .55 ml/min

How do these compare to water movement in other plant systems? There are several factors involved including the transpiration rate of water from the leaves, the transport rates up the plant stem and the uptake of water by the roots. Soil conditions and atmospheric conditions (humidity and temperature) will have considerable influence in addition to the plant morphology and regulatory mechanisms (see for example the paper by Camacho-B and colleagues who studied water transport in both some woody and herbaceous plant species [Camacho-B, 1974]). For our purposes the rate of water movement as well as the volume of water were of interest. In particular, how long would one need to wait before taking samples of higher leaves to determine if a particular mineral had been incorporated after being placed in the soil?

Joanna Gilbert on her website [Gilbert, 2018] asserts that xylem vessels form continuous pipes from the roots to the leaves through which water can move up through these pipes at a rate of 8 meters/hour, and can reach a height of over 100m. This translates into:

8 m/hr = 8 x 100 cm / 60 min = 13.3 cm/min

Our results are well within this range. If one compared cross-sections of channels through the stems to the Gilbert reference of tall trees, it is likely that the Moringa has very efficient transport compared to most plants; which stands to reason given its comparatively rapid growth rate. See also Jensen, 1961.

In followup experiments, later in 2016 and in 2017, the resolution time for resolving modest wilting of the tips ranged from 2 to 4 hours. At the end of the second season the main stalk had a diameter

of 1 5/8 inches (42 mm) at the base and a diameter of .75 inch (19 mm) at a height of 64 inches (1.62 meter).

The extent of wilting which was recoverable is seen in Figure 6-Image # 1. Recovery after watering is seen in Image #2 (Figure 7) at 1 hour and 19 minutes.

Figure 6
Wilting Image #1

Figure 7
Wilting Image #2 Partial Recovery

Apparent total recovery was observed almost 3 hours later (Figure 8 -Image #3).

Figure 8
Wilting Image #3 - Total Recovery

Later in the season, wilting of all the leaves that followed exposure to freezing temperatures was extreme and it was not reversible in the days that followed. Branches of leaves were removed for analysis and/or drying for making tea.

In the second season freezing temperatures (especially at night) were encountered in November that led to the wilting of leaves and stems. Five days after temperatures reached 28 deg. F., the plant looked as seen in Figure 9. The plant did not recover. Leaves were taken for analysis. Mineral content was determined for leaves taken at different plant heights.

Figure 9
Post Freeze Wilting

Yellowing of Leaves Considerations

Yellowing of leaves may be caused by mineral deficiences, over-watering, under watering, etc. [see reference to Blog: xman response to Raji, 2013]. In our observations we distinguished between spotty yellowing, versus uniform yellowing across the entire leaf versus an absence of color at all (chlorotic) as if the leaves had been bleached. Some of these patterns are indicated in the image seen in Figure 10

Figure 10

Selection Of Yellowing / Chlorotic vs. Fully Green Branches

It was initially assumed that yellowing was a deficit in chlorophyll (the green pigment in plants). This might occur if there were a deficit in nitrogen or in magnesium. Mg is bound to the four nitrogen atoms in the porphyrin rings of the chlorophyll molecule. We did not however find a

correlation between Mg level and yellowness as we first expected. But, there was a correlation between nitrogen level and yellowing. Upon further analysis it was determined that the amount of Mg needed to bind with chlorophyll was similar to the amounts measured in leaves. In other words, the Mg may be a limiting factor in some cases but not in others. It is known that Mg is associated with many other compounds and structures beside chlorophyll. The following analysis provides some perspective from other plant species.

1. Chlorophyll has a molecular weight 893.51 $g \cdot mol^{-1}$

Paddy rice seeds variety IR-64 (Oryza sativa) were planted and monitored for 10 days during which time the plant color changed from yellow to progressively darker green. It was also exposed to light for varying times each day with 9 hours being the norm. During this period the chlorophyll concentration increased from 0.015 g/l to 3.250 g/l and from 0.000 g/l to 0.774 g/l for chlorophyll a and b, respectively (Shibghatallah, 2013). Assuming the density is roughly equivalent to water (1 gm/ml), the total (a+b) can be expressed as:

2. 4.024 g/l = 4.02 mg/ml => 4 mg per gm Fresh Weight or <u>17.7 mg/ gm dry wt.</u>

In a study on Tonka bean (Dipteryx odorata Aubl. Wild) by Goncalves et al. [Goncalves, 2001], chlorophyll was found to range in concentration from 1.77 - 3.93 micromole/gm (FreshWeight) depending upon the light exposure. Using 3.5 as a point of reference, and converting this to grams Fresh Weight we multiply by the molecular weight of Chlorophyll to compute the weight in milligrams per gram of tissue (FW).

3. 3.5 micromole/gm x 893 g/mol ➔ 2187 micro gm Chl/ gm ➔ 2.18 mg Chl/gm FW

Converting this to a dry weight basis (using a factor of 4.4 wet/dry which was observed for Moringa leaves) we get:

4. 2.18 mg/gm FW x 4.4 wet/dry => <u>9.59 mg/ gm dry wt</u>

This is in the same range as the Shibghatallah result.

By comparison the Mg levels we found in Moringa as expressed in % were:

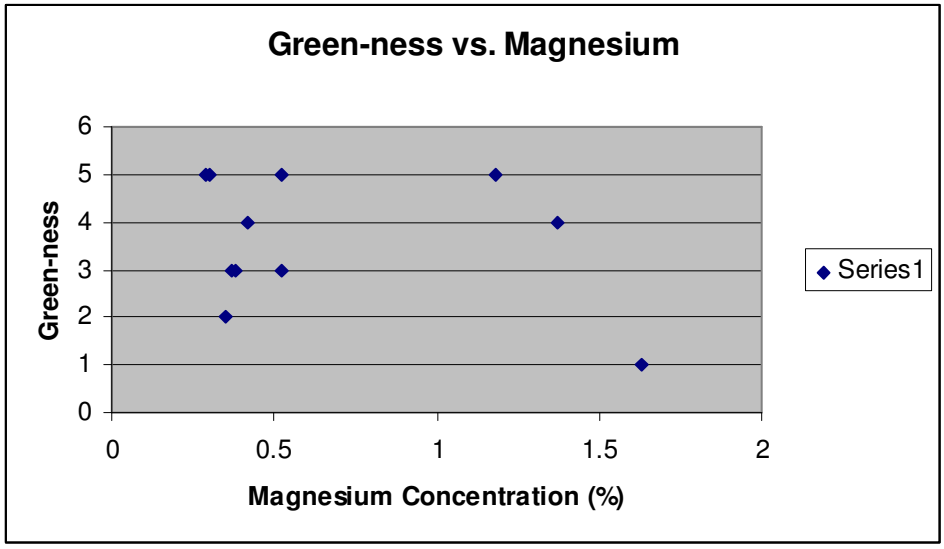
5. from .29 to 1.63 %

Converting to dry weights = .0029 to .0163 gm/ gm dry wt

<u>= 2.9 to 16.3 mg / gm dry wt.</u>

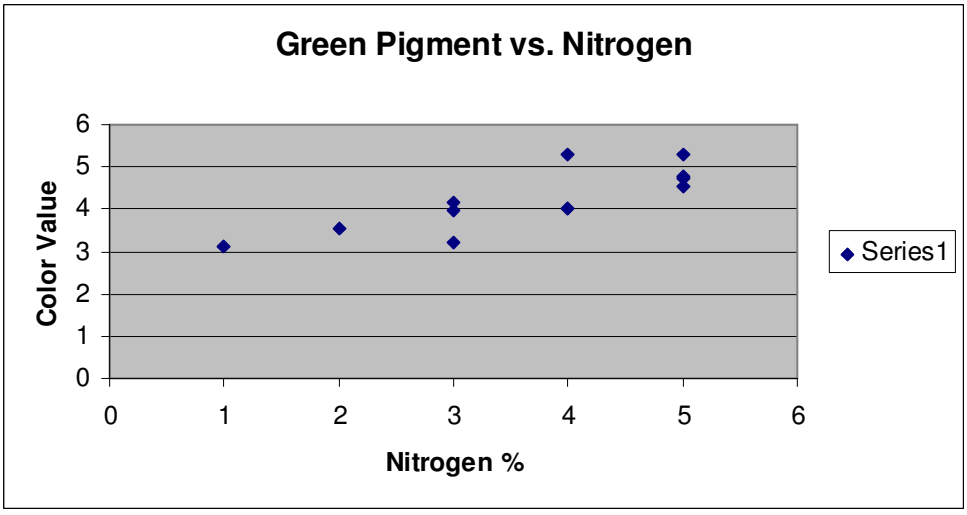
Without determining the chlorophyll content of the Moringa leaves, one cannot determine whether the Mg is a limiting factor or not. As seen in Figure 11, we found no positive correlation between Mg content and green-ness of the leaves. A score of 5 was considered normal dark green. Light green was scored as 4.0 whereas a score of 3 or lower was yellow. Note the combined/overlapping points at low Mg and a green value of 3. Mineral concentrations are given as a % grams per gram dry weight of leaves.

Figure 11
Magnesium and Green-ness



There are other minerals that are required for the synthesis of chlorophyll or its precursors. Greatest among these is nitrogen. Every chlorophyll molecule contains four nitrogen atoms that are associated with each of the four pyrole rings surrounding the one Mg ion. We did find a positive correlation between green-ness and nitrogen level as seen in Figure 12.

Figure 12
Nitrogen vs. Green-ness



An examination of the relationships between green-ness and other minerals was undertaken. In Figures 13 and 14 the relation between Green-ness and potassium and calcium is shown respectively.

The calcium data mimic somewhat the magnesium in suggesting a parabolic relationship. However additional data will be required to affirm whether there is an "optimal" concentration giving a peak greenness and a follow off on either side.

Figure 13
Potassium vs. Green-ness

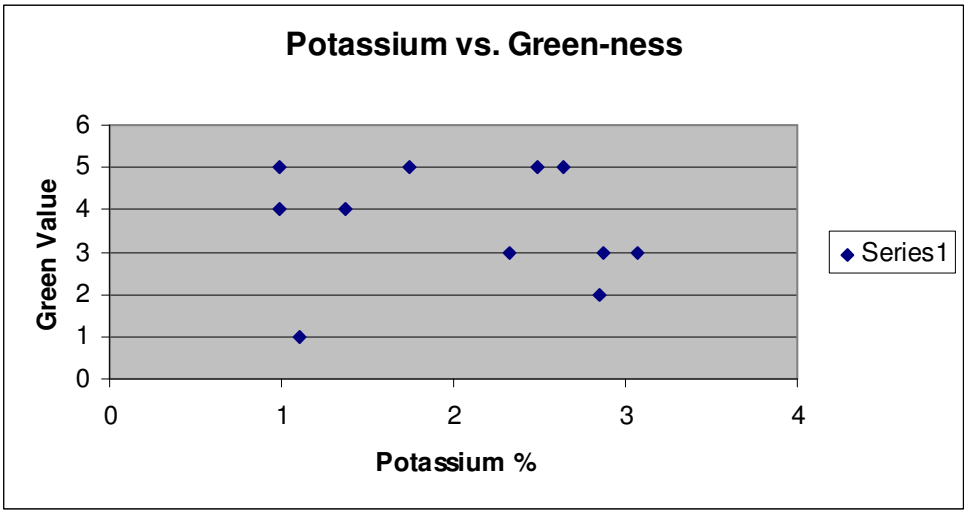
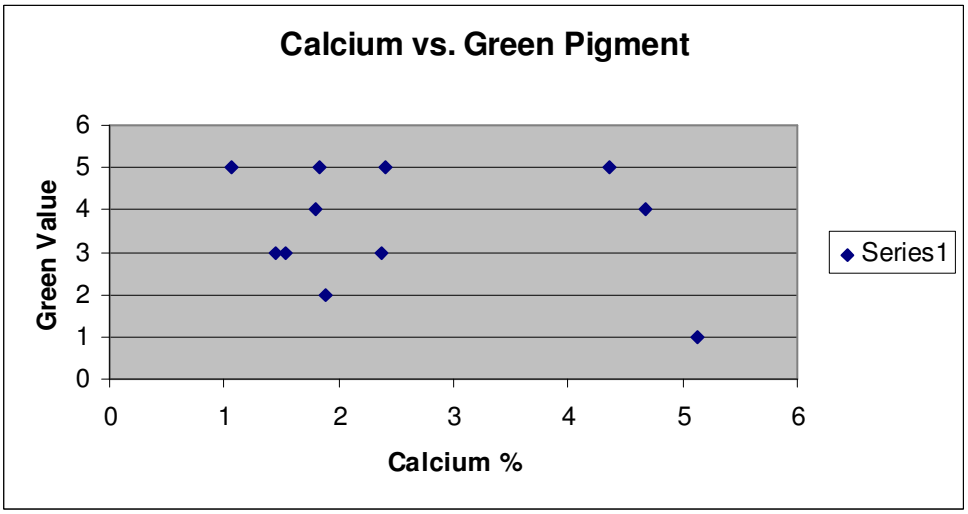


Figure 14
Calcium vs. Green-ness



Additional factors were considered for accounting for the yellowing of leaves. In the early plant growth and in growth of new branches, the leaves are green. This suggests that none of the nutrients were limiting initially. So, the yellowing or disappearance of chlorophyll at later stages remains a mystery. To probe this further, we examined the relationship between other minerals and green-ness with the following graphical results.

Iron-sulfur complexes are involved in the photosynthesis systems in chloroplasts (Nelson, 2005, p. 734). [Refer to phylloquinone and ferredoxin Fe-S proteins in the Photosynthesis I pathway]. Iron is also an integral part of cytochromes a, b, and c which are involved in photosynthesis (Nelson, 2005, p. 694). So, deficits of either iron or sulfur could compromise the plant. See Figures 15 and 16.

Figure 15
Iron vs. Green-ness

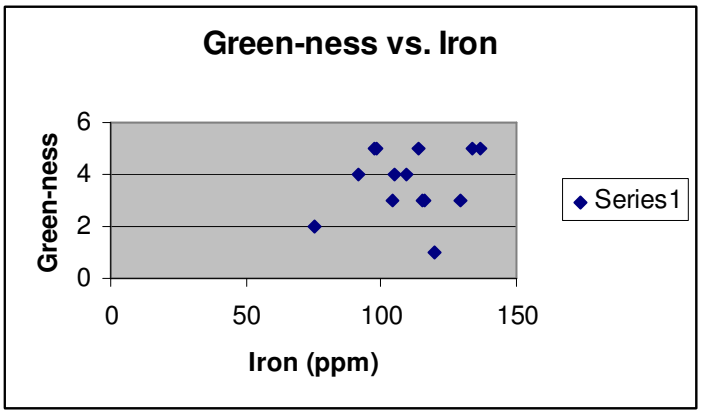
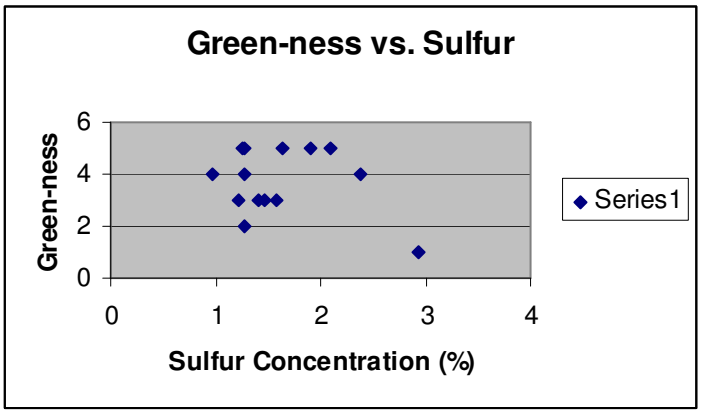
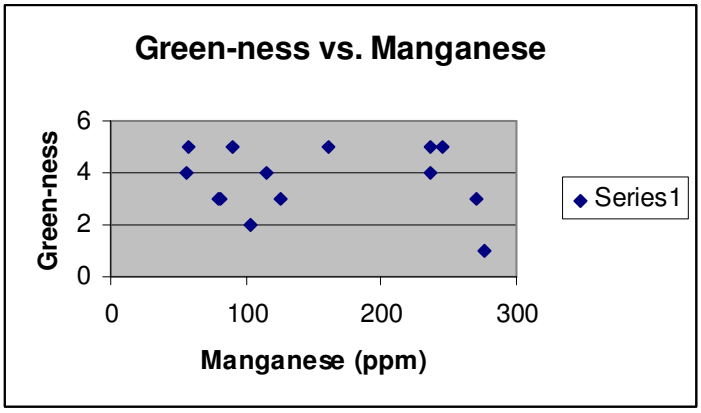


Figure 16
Sulfur vs. Green-ness



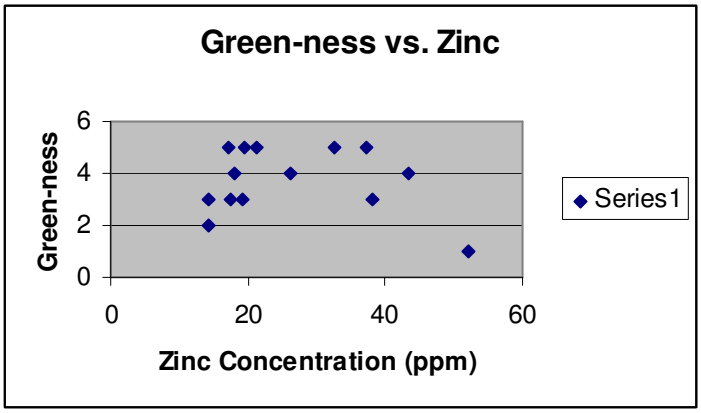
Manganese complexes are involved in the water-splitting activity that results in the formation of oxygen in the over-all photosynthetic process [Nelson, p. 739] . Manganese levels had no apparent correlation with green-ness as seen in Figure 17.

Figure 17
Manganese vs. Green-ness



Zinc is known for its role in the zinc finger protein that is comprised of 30 amino acid residues that form an elongated loop held together at the base by a single Zn++ ion, which is coordinated to four amino acid residues. Zinc fingers are associated with DNA and mRNA binding proteins.[Nelson, 2005, p. 1090] There was no obvious correlation between green-ness and Zn levels as seen in Figure 18.

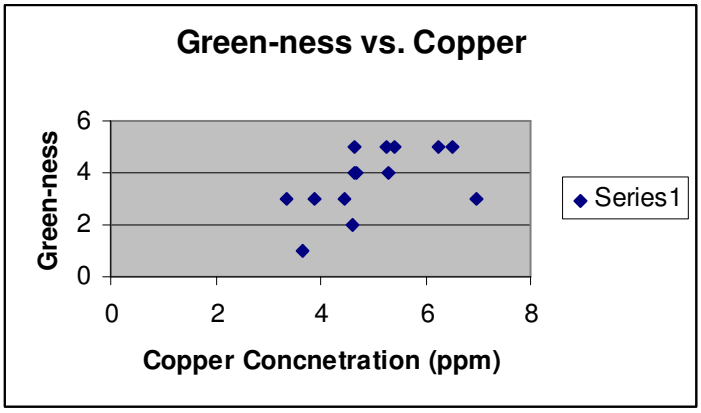
Figure 18
Zinc vs. Green-ness



Copper (Cu) is a part of the Complex IV process along with cytochrome c and the associated cytochrome oxidase enzyme. The mitochondrial subunit II contains two Cu ions complexed with the SH groups of two cysteine residues (Nelson, 2005, p. 700). As seen in Figure 19, there was a tendency to increase in green-ness with rising Cu concentration; but, the significance of this is unclear.

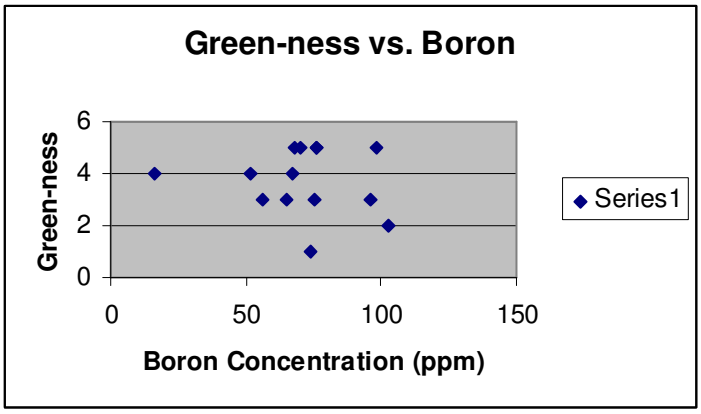
Another way of looking at the data is to state that lack of green-ness implies the presence of yellow-ness. In other words yellowing is associated with low copper.

Figure 19
Copper vs. Green-ness



Boron is important in cell wall integrity, cell division, plasma membranes, fruit and seed development, et al. Some functions of boron interrelate with those of nitrogen, phosporus, potassium and calcium in plants (Ahmad, 2009). There appeared to be no correlation between Green-ness and Boron concentration as seen in Figure 20.

Figure 20
Boron vs. Green-ness

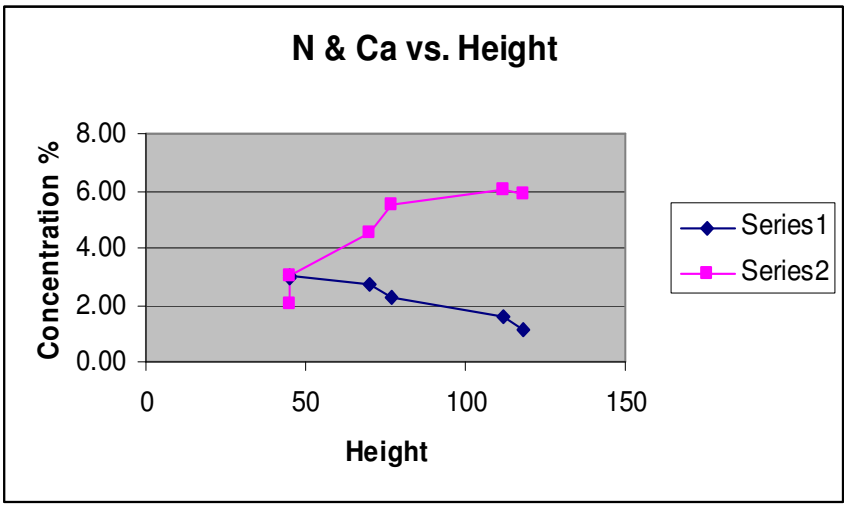


Minerals versus Height

Since the Moringa oleifera is such a fast growng plant and grows to be quite tall (over 9 feet within 180 days), it was of interest to determine whether the mineral content of the leaves was different at different heights. This would be important from a nutritional perspective as well as of scientific interest as to how efficient the mineral transport system was. It may also be important from a grower's perspective to justify pruning at a particular height. Pruning may be one of several factors that influences the onset of flowering and seed production. Height is obviously related to the age of the leaves as well. Lower leaves are older and upper leaves are younger.

Samples were taken at three different levels and the mineral contents compared. Following are some of the results. In Figure 21, Calcium is Series 1 (Blue) and Nitrogen is Series 2 (pink).

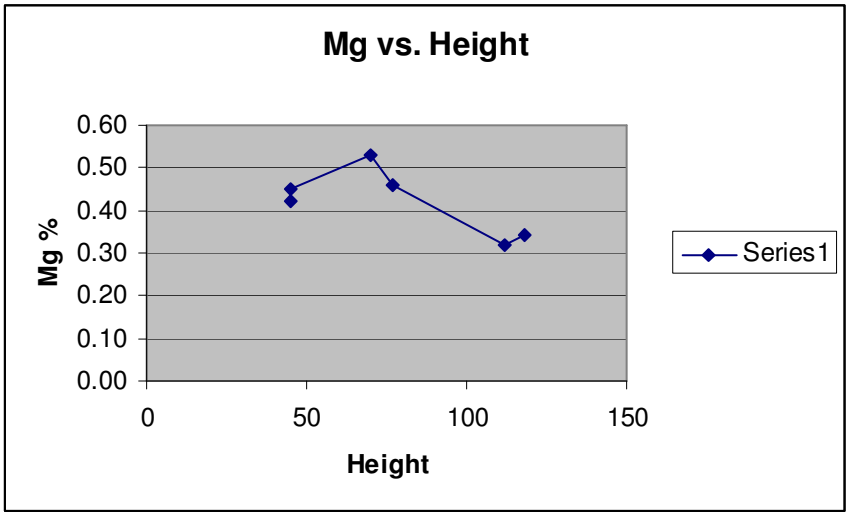
Figure 21
Nitrogen and Calcium vs. Height



It is noted that nitrogen levels increase with increasing height/younger leaves; whereas, calcium tends to decrease with height/young leaves.

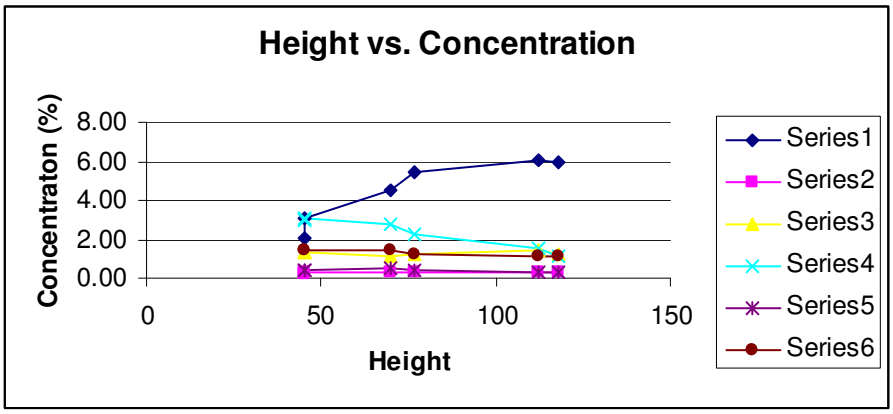
It is noted in Figure 22 that magnesium also tends to decrease with height although the trend is less pronounced.

Figure 22
Magnesium vs. Height



Putting all the major minerals together in one chart is seen in Figure 23. This highlights the main differences.

Figure 23
Height vs. Major Minerals Concentration

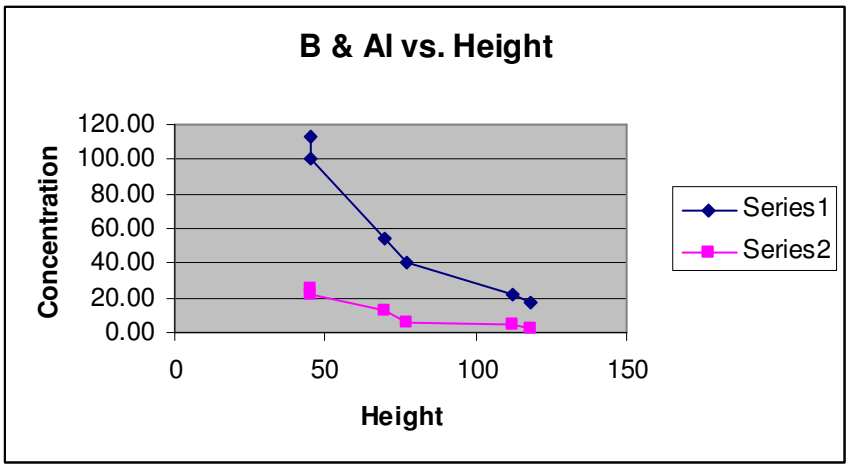


Series 1 - Nitrogen, Series 2 - Phosphorous, Series 3 - Potassium, Series 4 - Calcium
Series 5 - Magnesium, Series 6 - Sulfur

The lower concentration minerals are indicated in the figures below. The relationships between Boron and Aluminum vs. Height are indicated in Figure 24. Series 1 (blue) is Boron and Series 2 (pink) is Aluminum. Boron definitely drops off as the height increases. This is a little puzzling

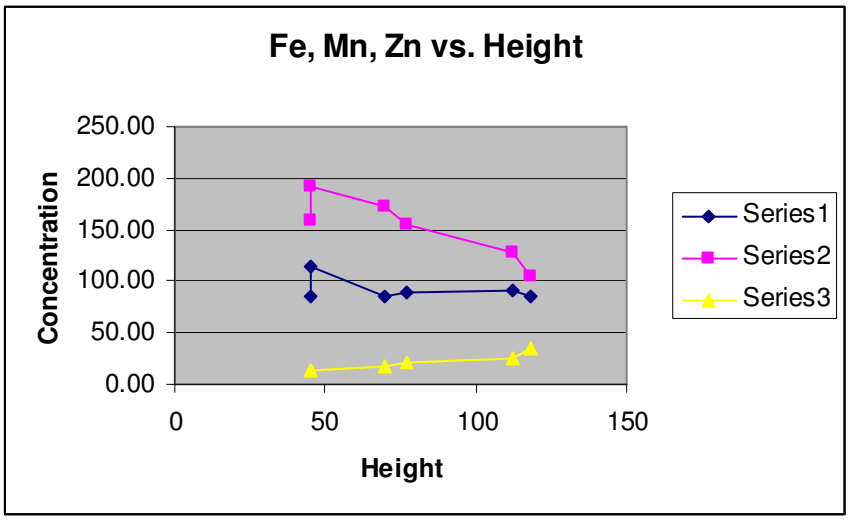
since Boron is known to be important for the growing tips and seed development among other things. Aluminum also decreases with height albeit to a lesser degree. The transport of these elements may not be as well developed as for other minerals. Whether this decrease is of biological importance or nutritionally important requires further investigation.

Figure 24
Boron and Aluminum vs. Height



The relationships between Fe, Mn and Zn vs. Height are indicated in Figure 25. The concentration is in ppm. Series 1 shows concentrations for Iron (blue). Series 2 shows concentrations for Mn (pink) and Series 3 shows concentrations for Zn (yellow). Manganese has a strong tendency to decrease with height. However, Fe appears indifferent to height/age. Zinc shows an increasing trend but it may not be statistically nor biologically significant.

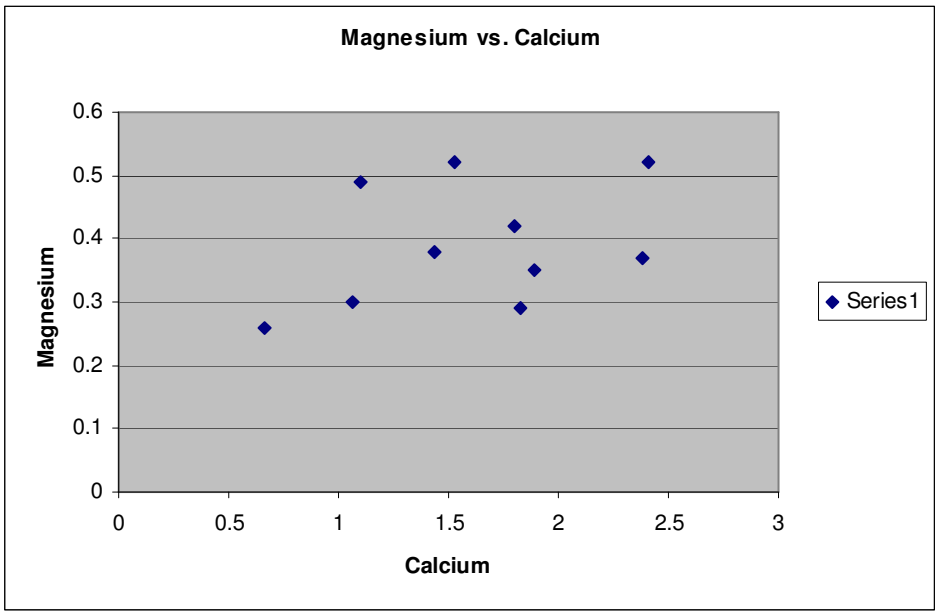
Figure 25
Fe, Mn, Zn vs. Height



Electrolyte Interactions

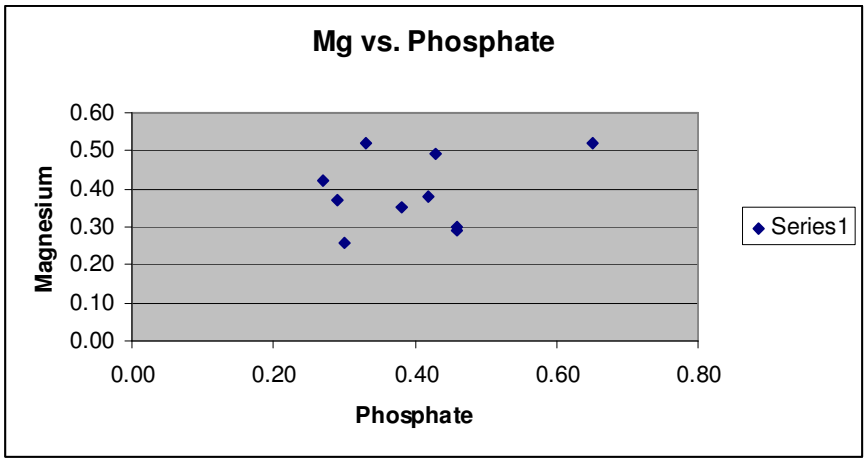
We investigated a number of relationships between electrolytes. It is known from other studies and other species (including animals) that Mg and Ca often compete for the same membrane channels or the same binding sites on proteins [Job, 1974] and the ratio between them is often as important as the actual levels. Thus, it was of interest to determine whether that was the case in this plant. In Figure 26, it does appear that as calcium increases, so too does magnesium.

Figure 26
Magnesium vs. Calcium



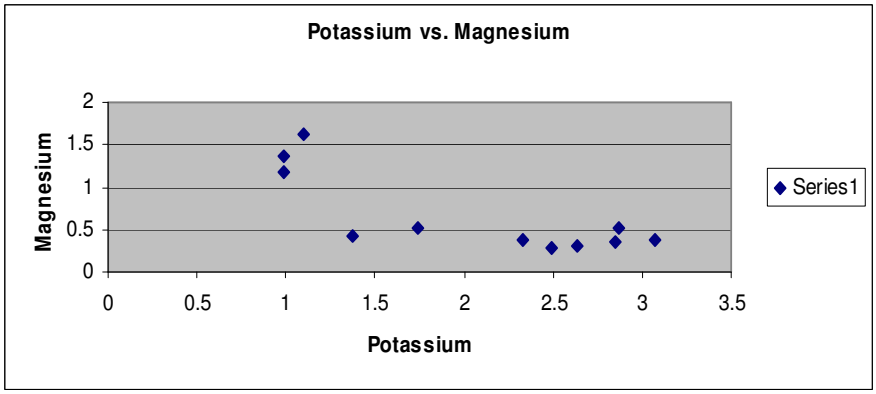
Magnesium is known to play a catalytic or direct role in most phosphorylating reactions. Thus, it was of interest to see whether there was a linear relationship between them. We found no apparent correlation between magnesium and phosphate except that for the highest phosphate level, Mg was also high as seen in Figure 27. It is noted that in the soil analysis, the phosphate levels tested well above the optimal levels.

Figure 27`
Magnesium vs. Phosphate



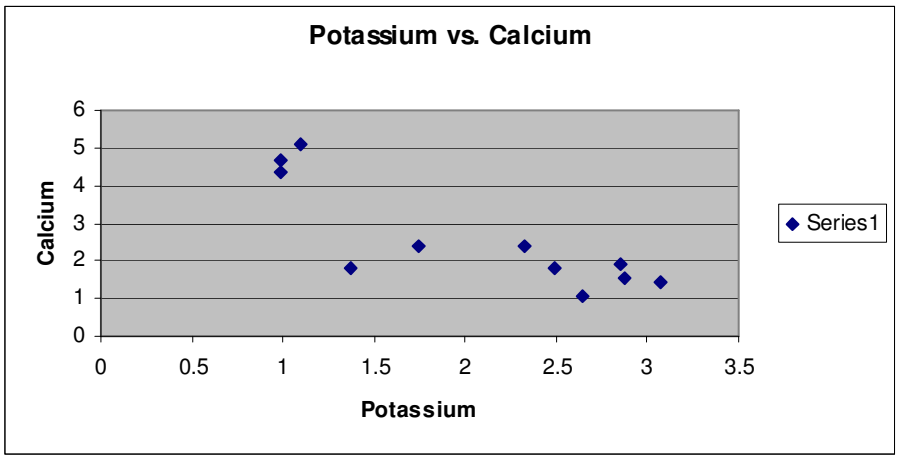
Potassium is a key electrolyte in maintaining membrane balances. It also is often associated with magnesium and calcium in maintaining membrane potentials and various enzyme activations. As seen in Figure 28, the highest Mg levels were at the lowest K levels; but, there was not a clear linear relationship between them. Mostly magnesium was low for all the higher levels of potassium.

Figure 28
Potassium vs. Magnesium



We found an inverse correlation between potassium and calcium (potassium was higher when calcium was lower) as seen in Figure 29. This is an interesting observation but it is unclear as to the implications. It is noted that in the soil analysis, the potassium levels observed late in the first season tested well above the optimal levels.

Figure 29
Potassium vs. Calcium



DISCUSSION AND CONCLUSIONS

The current project started with the planting of 5 seeds of Moringa oleifera in a pot kept outdoors beginning in late April, 2016. Two of the seeds produced sprouts but only one of the sprouts lived to maturity. All of the mineral analyses were based upon that one plant - the same plant that survived a winter-die-back period and sprouted new growth the following spring. Samples were taken so that the plant served as its own control for different hypotheses tested; however, it would be risky to extrapolate the results to other Moringa plants grown in other climates and under different conditions.

It was disappointing that the plant did not produce flowering and seed pod formation over the two seasons; but, perhaps this will occur in the third season. Based upon the literature, this is not without precedence.

A number of issues were encountered; namely, periodic wilting and pre-mature yellowing of leaves. These issues led to the undertaking of further analysis. With respect to wilting, this provided an opportunity to measure water transport rates which can serve as a benchmark for follow-up studies. We found water to move up the main stalk at the rate of 1 cm / min and the volume transfer rate was estimated to be 100 ml/3 hour which would translate to 0.55 ml/min. Late in the second season the cross-section of the main stalk varied from 42 mm at the base to 19 mm at a height of 64 inches (1.62 meters). These are useful reference points for comparing water transport in other plants.

The water consumption increased from less than 1 liter per day to nearly 3 liter per day over the course of the summer of 2017. At the end of the second season (after drying out for 2 months), The over-all weight of the plant in its pot with soil intact was 47 pounds (23.3 kg). This was the weight when it had been stripped of its leaves, the main stalks cut back to under seven feet tall, and the soil devoid of any recent watering.

With respect to pre-mature yellowing, it provided an opportunity to examine the role of various minerals in maintaining a healthy "green-ness." An analysis of chlorophyll and its requirement for Nitrogen and Mg was made. Mg does not appear to be a limiting factor although nitrogren may be. A nitrogen deficit was also suggested by the soil analysis (but not confirmed by direct measurement). This suggestion was supported by our finding of a positive correlation between green-ness and nitrogen level in the leaves.

One additional factor that may account for the pre-mature yellowing of leaves is the excess of phosphorous and potassium in the Miracle Gro potting soil. In the future, this will be diluted out with other soil types.

Mineral levels as a function of height from which the leaf samples were taken revealed some interesting if not definitive results. Boron definitely drops off as the height increases. This is a little puzzling since Boron is known to be important for the growing tips and seed development among other things. Aluminum also decreases with height albeit to a lesser degree. The transport of these elements may not be as well developed as for other minerals. Whether this decrease is of biological importance or nutritionally of importance requires further investigation.

Other interesting tendencies were that as calcium increases, so too does magnesium. We also found an inverse correlation between potassium and calcium (potassium was higher when calcium was lower). These are interesting observations but it is unclear as to the implications.

In the final analysis the Moringa tree offers many opportunities for studies of minerals and various growth and plant health indicators. It is hoped that these preliminary studies will be useful to others in probing the mysteries of why this plant offers many health benefits and how we might grow it more effectively to meet the needs of people having nutrient deficit diets.

FIGURES

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> *Moringa's leaves turn yellow for 2 reasons, 1) Soil too dry. 2) Soil too moist. Usually yellow leaves are caused by the 2nd reason. I have about 8 of these trees and I have seen that even a little extra water will cause the leaves to turn yellow and drop.*
> *If you are sure that it is not any of the above 2 reasons, then check to see if you are providing correct nutrition, check pH level of the soil, etc.*

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> The moringa tree, Moringa oleifera, has probably been the most popular plant in ECHO's seed bank of underutilized tropical crops. The tree is native to India but has been planted around the world and is naturalized in many locales. Moringa goes by many names. In the Philippines, where the leaves of the moringa are cooked and fed to babies, it is called "mother's best friend" and "malunggay." Other names for it include the benzolive tree (Haiti), horseradish tree (Florida), Nébéday (Senegal) and drumstick tree (India).

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WEBSITES RELATING TO MORINGA

Moringa News network of people interested in Moringa and clearinghouse for Moringa information: http://www.moringanews.org/

Educational Concerns for Hunger Organization (ECHO), Florida
https://www.echocommunity.org/en/search?q=MORINGA+OLEIFERA

_____ "Moringa Nutrition Data. What Makes Moringa a Superfood" from Moringa Source: https://www.moringasource.com/pages/moringa-product-data

http://moringatrees.org/
22 Shelter Rock Lane 261, Unit 3 Danbury, CT 06810, USA
https://miracletrees.org/#moringadocuments

Note: The preceding two sites are commercial sites that extol the virtues of Moringa, their ingredients and related products. However, there are some references made to studies that we presume are less self-serving.

IMAGE INFORMATION DETAILS

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http://www.iprsinc.org and http://www.enbede.com

IPRS is a non-profit corporation holding a 501(c)3 IRS tax exemption.

Appendix

Product: Miracle-Gro Potting Mix 0.21-0.11-0.16
Product #:0698-0126

GUARANTEED ANALYSIS	(%)	REPORTED METALS	(ppm)
Total Nitrogen (N)	**0.2100**	Arsenic	**0.9740**
Available Phosphoric Acid (P_2O_5)	**0.1100**	Cadmium	**0.4860**
Soluble Potash (K_2O)	**0.1600**	Cobalt	**4.7400**
Calcium (Ca)		Mercury	**0.0334**
Magnesium (Mg)		Molybdenum	**1.4600**
Sulfur (S)		Nickel	**1.8500**
Boron (B)		Lead	**3.7900**
Chlorine (Cl)		Selenium	**1.4600**
Cobalt (Co)		Zinc	**18.3000**

State of Washington Fertilizer Product Registration site
https://agr.wa.gov/PestFert/Fertilizers/FertDB/prodinfo.aspx?pname=2882

The Potting Mix product is formulated from (one or more of the following: processed forest products, peat, coir, and/or compost), and sphagnum peat moss, perlite, fertilizer (as above), and a wetting agent.

Product Miracle Gro 24-8-16 Water Soluble All Purpose Plant Food
Scotts Miracle-Gro Products Inc - Marysville, Oh

Heavy Metals (in Parts Per Million)		
Arsenic: < 0.63	**Cadmium:** < 0.315	**Mercury:** < 0.0283
Nickel: < 0.479	**Lead:** 4.15	

Guaranteed Analysis		
Total Nitrogen: 24%	**Avail. Phosphate:** 8%	**Sol. Potash:** 16%
Calcium:	**Magnesium:**	**Sulfur:**
Boron: 0.02%	**Chlorine:**	**Cobalt:**
Copper: 0.07%	**Iron:** 0.15%	**Manganese:** 0.05%
Molybdenum: 0.0005%	**Sodium:**	**Zinc:** 0.06%

State of Oregon Fertilizer Product Registration site ss of: 2/28/2018
http://oda.state.or.us/dbs/heavy_metal/detail.lasso?-op=eq&product_id=4552

Quality of Water Used for Watering Plants and Making up Fertilizer Solutions

Substance (Unit of Measure	**Amount Detected**	**Range Low-High**
Alkalinity (ppm)	42	NA
Hardness (ppm)	35	NA
Iron (ppm)	.01	NA
Manganese (ppm)	.02	NA
pH (units)	8	6.5-8.5
Raw Total organic Carbon (ppm)	7.3	6.3-8.8
Sodium (ppm)	32.3	NA
Regulated Substances		
Sulfate (ppm)	41.6	NA
Nitrate (as Nitrogen) (ppm)	1.41	ND-1.41

City of Sanford Water Treatment Plant: Unregulated and Other Substances from CCR-49, Sampled 2008 (old report). Data for hardness measured throughout the year of 2017 was also obtained with comparable results. Water from Cape Fear River and two wells.

Water Hardness is measured according to Standard Methods: 2340C: EDTA Titrimetric Method (Hardness). Standard Methods Online -- Standard Methods for the Examination of Water and Wastewater. http://standardmethods.org/

Manganese is measured according to the *Direct Air-Acetylene Flame Method. See* NEMI Method Summary - 3111B at *https://www.nemi.gov/methods/method_summary/5703/.*