Feasibility of Growing Moringa in a Temperate Climate: Lessons and Insights I

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 objectives was to determine the feasibility of growing Moringa in a more temperate climate (North Carolina at latitude/longitude in decimal degrees format 35.400351, -79.111720) and to harvest the leaves and seeds for potential use for health improvement. Another objective was to determine whether the mineral profile of the leaves compared 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) and for which additional biological factors have been determined. A more complete analysis of biological factors and analysis of mineral interactions is provided in another paper by the author (Job, 2018c).

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 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 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 for the first 80 days shown in Figure 1. The full season growth is indicated in Figure 2.

Figure 1
Moringa Growth April 27th to June 27th, 2016

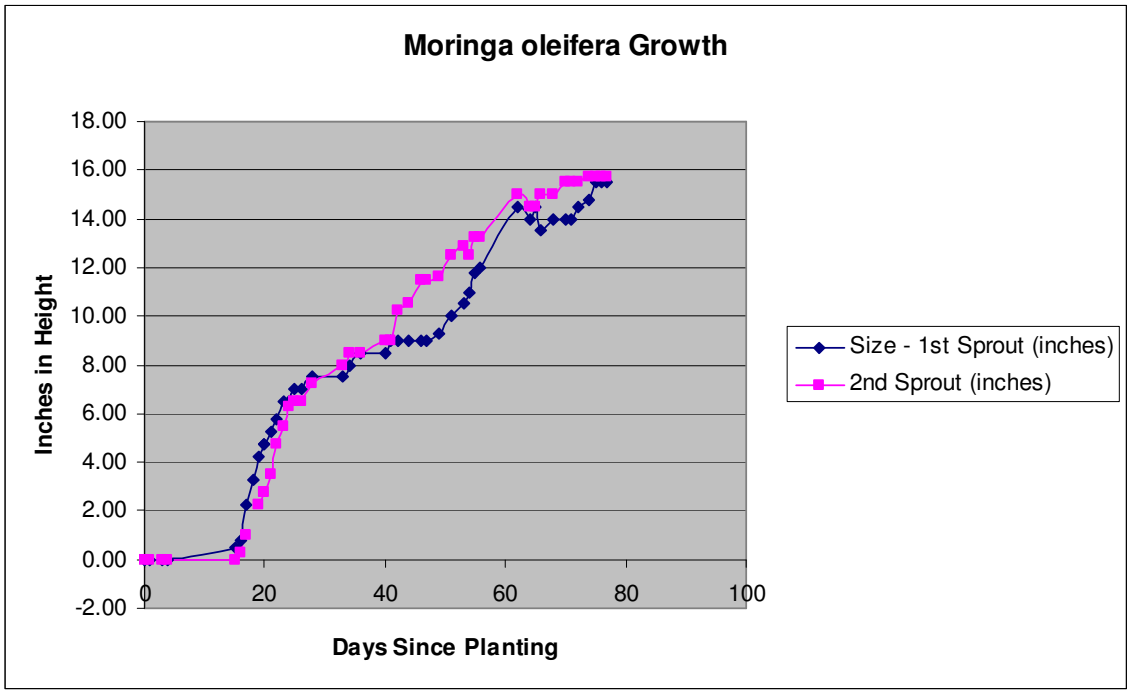
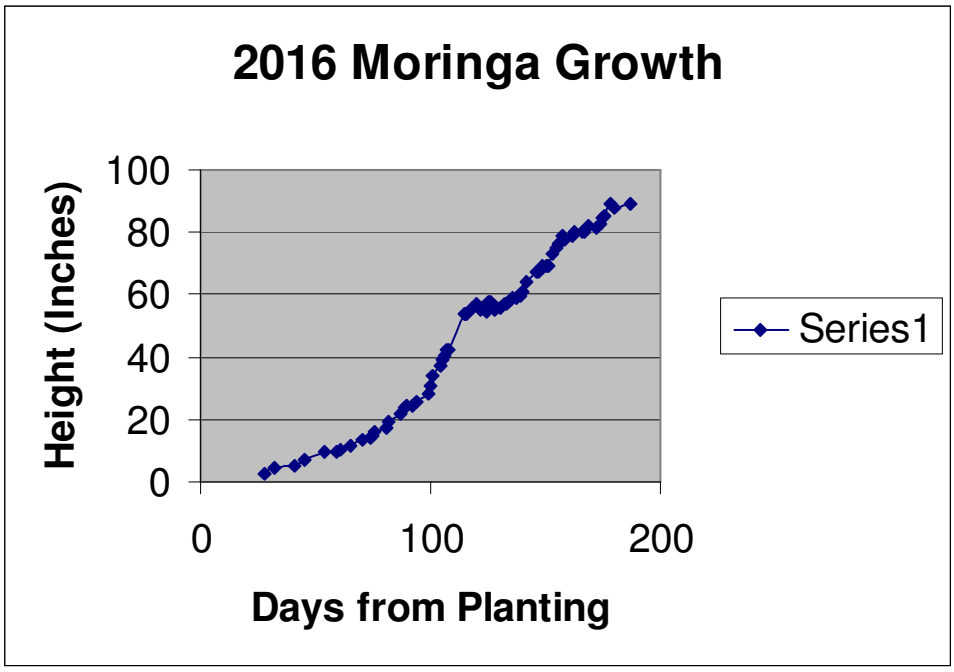


Figure 2
Moringa Growth Season 1



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

Figure 3 shows a photo of the growth of two seedlings after about 30 days. Note that two of the five seeds planted in this pot formed sprouts. The smaller one in the upper right hand corner was ultimately abandoned. The appearance of the main surviving plant by mid-August is shown in Figure 4.

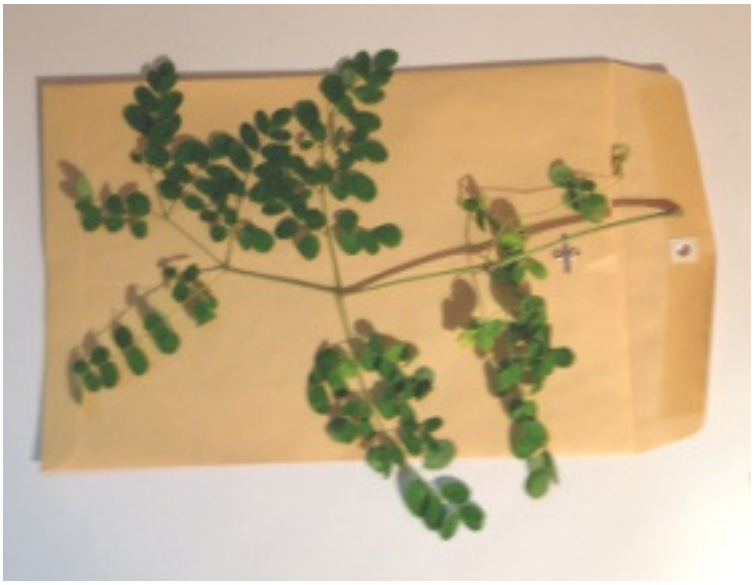
Figure 3
Moringa at May 29, 2016

Figure 4
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 (shown in Figure 6).

Figure 5 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 5
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 6.

Figure 6 Second year Growth

The photo in Figure 6 was taken August 31, 2017. Over-all height is 109 inches. The yard sticks are shown end-to-end against the white backdrop. Some branches were removed for tissue analysis during this period. Image ID 2017-Oct 021crp.jpg.

Image 6. Moringa near end of second growing season. As of (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 tissue analysis at different periods and under different

conditions. Other branches were removed and dried for use as a tea. The photo was taken October 24, 2017. Photo ID (from Moringa 2017 folder) 2017-Oct24-004-sc.jpg.

Figure 7 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 7
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 [Blog, xman]. A moisture meter was used to prevent over-watering. 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.

A more detailed analysis of water transport was undertaken and appears in a companion paper by D. Job, 2018c. It was concluded that the transport rate is within the range of other plants in which transport has been measured. It is likely that the Moringa has very efficient transport compared to most plants; which stands to reason given its comparatively rapid growth rate.

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. Mineral content was also determined at different plant heights.

The extent of wilting which was recoverable is seen in Figure 8, Wilting Image # 1. Recovery after watering is seen in Figure 9, Wilting Image #2 at 1 hour and 19 minutes and the later at almost 3 hours (Figure 10, Image #3).

Figure 8
Wilting Image #1

Figure 9
Wilting Image #2 Partial Recovery

Figure 10
Wilting Image #3 - Total Recovery

Later in the first 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 11. The plant did not recover. Leaves were taken for analysis. Mineral content was determined for leaves taken at different plant heights.

Figure 11
Post Freeze Wilting

Yellowing of Leaves Considerations

Yellowing of leaves may be caused by mineral deficiences, over-watering, under watering, etc. [Blog, xman response to Raji]. 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 12

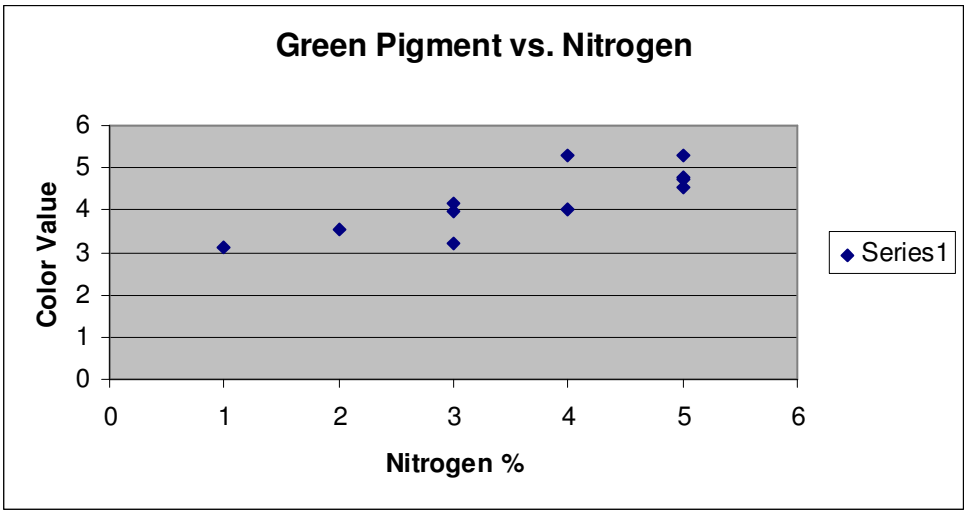
Figure 12
Selection Of Yellowing / Chlorotic vs. Fully Green Branches

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 (as reported in D. Job, 2018c) 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.

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 13. 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.

Figure 13
Nitrogen vs. Green-ness



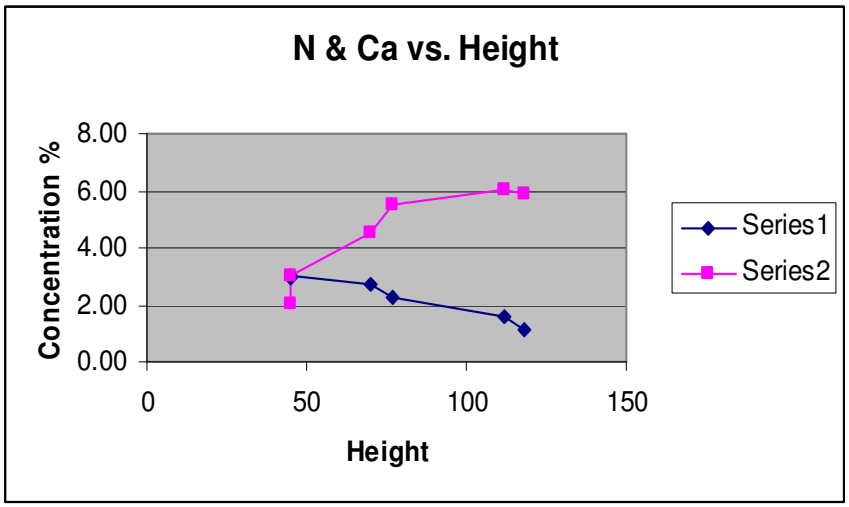
An examination of the relationships between green-ness and other minerals was undertaken. These results are reported in another paper (D. Job, 2018c). The conclusion was that in terms of mineral levels, the best predictor of green-ness is the level of nitrogen in the leaves.

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.

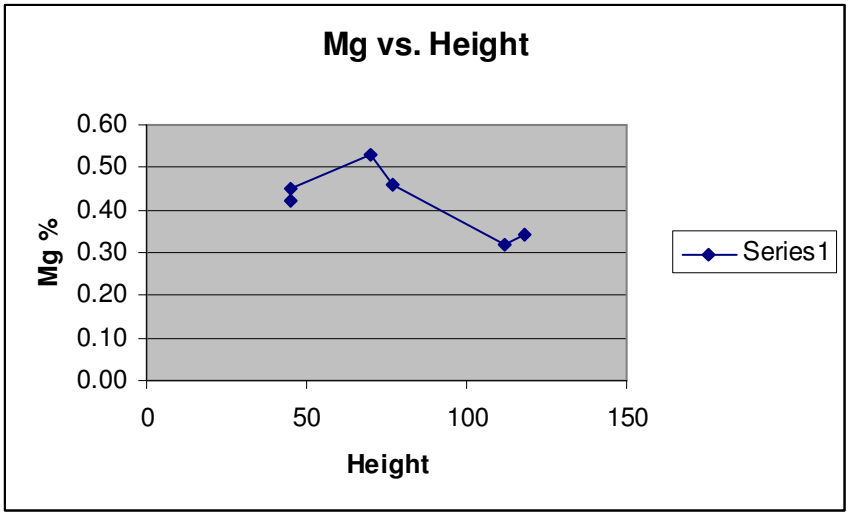
Samples were taken at three different levels and the mineral contents compared. Following are some of the results. In Figure 14, Calcium is Series 1 (Blue) and Nitrogen is Series 2 (pink).

Figure 14
Nitrogen and Calcium vs. Height



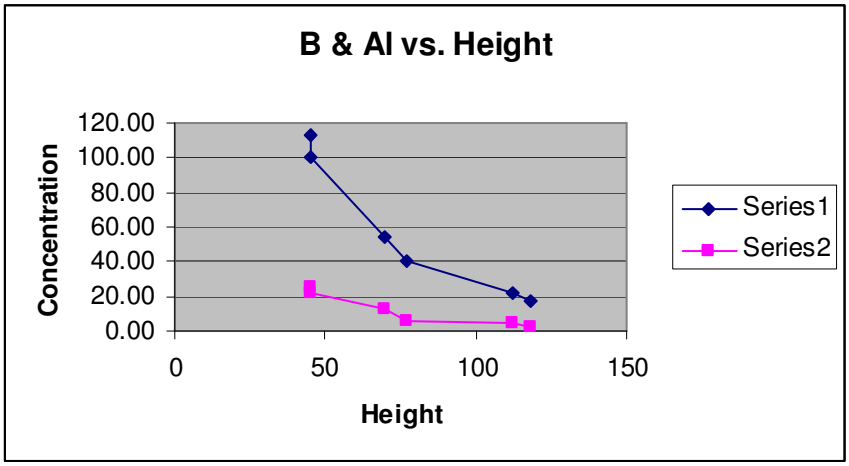
It is noted that nitrogen levels increase with increasing height/younger leaves; whereas, calcium tends to decrease with height/younger leaves. It is noted in Figure 15 that magnesium also tends to decrease with height although the trend is less pronounced.

Figure 15
Magnesium vs. Height



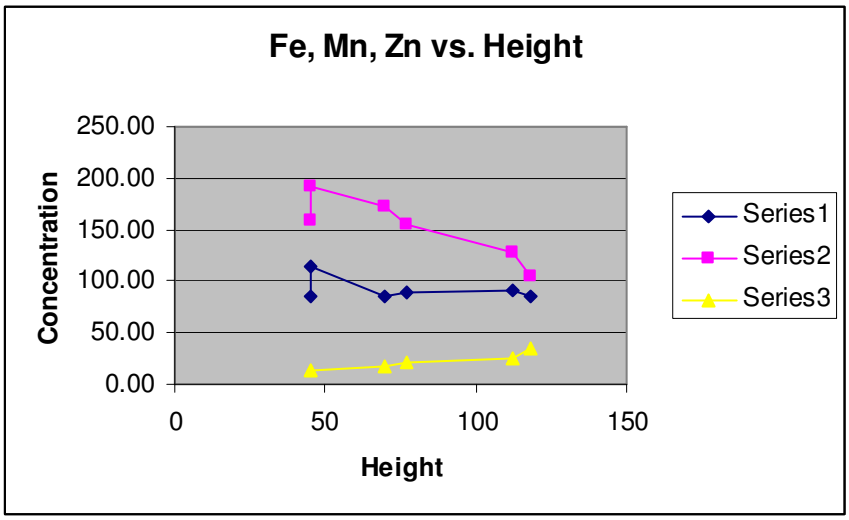
The relationships between Boron and Aluminum vs. Height are indicated in Figure 16. Series 1 (blue) is Boron and Series 2 (pink) is Aluminum. Boron definitely drops off as the height increases. This is a little puzzling since Boron is known to be important for the growing tips and seed development among 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 of importance requires further investigation.

Figure 16
Boron and Aluminum vs. Height



The relationships between Fe, Mn and Zn vs. Height are indicated in Figure 17. 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 17
Fe, Mn, Zn vs. Height



Electrolyte Interactions

In a separate paper, we investigated a number of other relationships between electrolytes (Job, 2018c). We found an inverse correlation between postassium and calcium (potassium was higher when calcium was lower).

We found that when magnesium was at its highest levels, potassium was low; but, it was not a linear relationship and mostly magnesium was low for all the higher levels of potassium.

We found no apparent correlation between magnesium and phosphate except that for the highest phosphate level, Mg was also high.

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.

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. So, the feasibility of growing Moringa in North Carolina for seed production has not yet been established. However, growing Moringa for leaf production was established. Whether it is economically feasible to compete with importers of Moringa grown in more tropical climates remains to be determined. A number of issues need to be resolved. Among those is the issue of being able to grow to maturity to produce our own seeds. Another issue is how to prevent wilting during the growing season. A better method of assessing water needs and potential over-watering is required. Providing a more sandy soil and drainage/ aeration for the root system may be helpful for optimal growth.

There is also the issue of pre-mature yellowing of leaves. Resolving the water control issues may help in this regard. Soil pH and nutrient contents are other potential factors along with pest and/or infection control. There were some indications of fungal invasion; but no treatments were given. In most instances yellowing of leaves (whether spotty or homogeneous) occurred on a branch by branch basis. That is, one branch would have normal coloration and leaves on an adjacent branch (above or below) would gradually turn yellow and then fall off.

To extend the growing season, it may be a good investment to provide supplemental lighting and heating to extend growing season. In order to raise the plants in a greenhouse, pruning may be necessary to prevent it from growing through the roof. Some growers report in the literature that pruning to produce a broader plant rather than a taller one is adviseable. That approach will be explored in future experiments.

The author is not aware of studies on photoperiodic sensitivities of the Moringa either as it relates to growth or as it relates to triggering of the flowering and seed production stages. This is another area for future research.

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 in many parts of the world and in many climates.

FIGURES

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https://www.houzz.com/discussions/1727056/moringa-plant-leaves
Moringa plant leaves rajiramMay 14, 2013 [xman response to Rajiram].

> *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 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 is a 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

All photographs and charts are by D. Job and are Copyright protected. Written permission is required for their use. Charts were developed using Microsoft Excel™.

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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/.*