THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF HORTICULTURE

INTEGRATED PEST MANAGEMENT (IPM) TECHNIQUES FOR *MORINGA OLEIFERA*

JENNIE DIEHL
SPRING 2014

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree in Horticulture
with honors in Horticulture

Reviewed and approved by the following:

Ricky Bates
Associate Professor of Ornamental Horticulture
Thesis Supervisor

Kathleen Kelley
Professor of Horticulture Marketing and Business Management
Honors Adviser

Signatures are on file in the Schreyer Honors College.

ABSTRACT

Moringa has been grown traditionally for ornamental purposes but more recently has been brought into cultivation. As this is occurring, more horticultural research must be done to improve its productivity in terms of integrated pest management. There is little information available on control of *Moringa* pests. Research presented in this thesis explores environmentally sound techniques of controlling pest problems that impact *Moringa*. *Moringa oleifera* and *Moringa peregrina* were grown in preliminary greenhouse trials to determine growth characteristics and possible pest resistance of different ecotypes. Measurements of height, number of flowers, pest incidence, and pest severity were recorded. This preliminary trial showed substantial differences in growth parameters between ecotypes. This study also evaluated the effects of kaolin clay in managing pest problems on *Moringa*. In this study, *M. oleifera* seedlings were grown in a greenhouse free of insects and later treated with kaolin clay treatments at recommended, half, and 2X rates, along with a water control treatment for comparison. Eight replicates were conducted for each treatment in this single study. Nine week old *M. oleifera* seedlings were introduced into a greenhouse with an established pest population. The plant height, pest incidence, and pest severity were recorded for these treatments. No kaolin treatments were significantly different from control, but there appeared to be increased insecticidal response to the half rate compared to label rate for spider mite incidence. Two applications of kaolin treatments were applied since the kaolin product did not adhere well to the *M. oleifera* leaf surface. The lack of adhesion was most likely the main reason why kaolin did not serve as an efficient tool in integrated pest management. In this study, kaolin clay was not effective at controlling pests on *M. oleifera*. Better understanding of the leaf surface of *Moringa* is a key area of research for future studies.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to thank Dr. Ricky Bates for working with me on my undergraduate thesis. I am especially thankful for the experience in Thailand and Cambodia that he facilitated which allowed me to identify the possibilities of my research. I would also like to thank the greenhouse staff, in particular Scott DiLoreto, for helping me conduct my experiments. I am especially grateful for all the support that my friends and family provided, exclusively Tosh Rung.

Chapter 1

Literature Review

Moringa is a subtropical tree native to the Indian subcontinent (Ramachandran, 2001). *Moringa* grows in countries with the highest rates of malnutrition, exactly where it is needed the most. It has been called the miracle tree, horseradish tree, mother's best friend, never die, and drumstick tree and has many medicinal uses for skin, respiratory, digestive, famine, and malnutrition (Ramachandran, 2001). *Moringa* leaves are extremely high in iron, calcium, potassium, vitamin A, and protein (Ramachandran, 2001). *Moringa* seeds are used to purify water by coagulation (Palada, 1996). They also contain compounds such as 4-L-alpha-1-rhamnosyloxybenzyl isothiocyanate that give it the ability to purify water containing guppies (*Poecilia reticulata*), protozoa (*Tetrahymena pyriformis*), and bacteria (*Escherichia coli*) (Palada, 1996). For a tree that can provide so many wonderful things, the potential that *Moringa* holds for benefiting our world needs to be considered.

Currently, hunger, lack of clean water, and poverty in the developing world are the major contributors to the global food crisis. Malnutrition is the major cause of infant mortality, particularly in the tropics and sub-tropics. Worldwide it is estimated that one billion people are undernourished (Nature, 2010). The problem is not because there is not enough food. The problem is that the food does not end up where it is needed the most. Estimates say that 30% of the food produced goes to waste (Nature, 2010). Hunger is not going away anytime soon. That is why there is a great need to develop local, sustainable solutions to prevent malnutrition and water-borne disease caused by impure drinking water. *Moringa* is one of these solutions.

The *Moringa* tree is playing a significant role in poverty alleviation. *Moringa oleifera* has been grown traditionally as a backyard tree, but more recently has been brought into cultivation. It has been cultivated in rural areas to improve nutritional security and purify drinking water. As this is occurring, more horticultural research must be done to improve its productivity. *Moringa* has so much potential to be grown commercially as an agronomic or horticultural crop. *Moringa* is commonly used as a hedgerow, windbreak, or as a living fence (Palada, 1996). *Moringa* can serve as a great addition to any of the five integrated practices of agroforestry plots (forest farming, alley cropping, silvopasture, riparian buffers and windbreaks). It can also be used as a support system for vining plants such as bean. *Moringa* leaves are commonly grown as forage or fodder, as well as human consumption for fresh or cooked greens. Per gram, the nutrition content of dried *Moringa* leaves can be very concentrated, making it a perfect supplement to any dish (Price, 2007).

Moringa is an underutilized species that has the potential to save millions of lives. Underutilized species like *Moringa* need to be studied to optimize their use in the future. If agriculture is going to continue to advance, underutilized species must be researched. They can improve diets, nutrition, stability, and income in the areas it is needed most. Of all the plant species in the world, very few are actually recognized as food crops. It is extremely dangerous to rely on such a small amount of genetic diversity to provide the world’s food and energy needs. Diversifying agricultural commodities not only rids agriculture of monocultures that are dangerous, but it also increases biodiversity that is often underexploited in the present day world. In order for agriculture to meet the needs of the ever increasing population into the future, it must be able to produce more food using the same amount of land without damaging the environment. Growing *Moringa* is one of the ways this goal can be achieved.

Chapter 2

Preliminary Experiment

Introduction

Moringa is an underutilized crop species. Since it has such an array of uses, research on potential commercialization must mirror the various ways *Moringa* is used throughout the world. *Moringa* is used as a vegetable, spice, oil, water coagulant, medicine, nematicide, fungicide, fodder, fence, trellis, firewood and ornamental plant (Palada, 1996). Some of the more recent research conducted on *Moringa* was at the University of the Virgin Islands Agriculture Experimental Station and the nonprofit, private, volunteer organization Educational Concerns for Hunger Organization (ECHO). These organizations are working to find appropriate ecotypes of *Moringa* for areas of cultivation. They have also worked to find appropriate ways to dry *Moringa* leaves.

Since *Moringa* has not been previously grown commercially, there is little research that has been conducted on the horticultural techniques that are best for *Moringa* cultivation. Little research on *Moringa* has been conducted in the United States because the tree can only grow in the tropics and subtropics. Two species of great interest are *Moringa oleifera* and *Moringa peregrina*. *M. oleifera* is one of the most widely cultivated *Moringa* species because it can be easily propagated asexually and *M. peregrina* is important because it is high in antioxidants. This study seeks to identify horticultural characteristics of *M. oleifera* and *M. peregrina* under greenhouse conditions. By growing *Moringa* seed from subtropical regions across the world in the same conditions, plant growth characteristics, ecotypes, natural pest resistance, and other notable qualities may be able to be identified.

Materials and Methods

In this preliminary experiment, *M. oleifera* and *M. peregrina* were grown at The Pennsylvania State University greenhouse B, section 16 located in University Park, PA at N 40.802098, W 77.862497. Moringa seeds were obtained from the ECHO seedbank and World Vegetable Center. Seed origin and cultivar name can be viewed in Table 1.

Table 1. Moringa seed origins

Number	Species	Pedigree/cultivar name	Origin country	Seed amount
TOT4100	oleifera	LA-MU	Taiwan	5
TOT4880	oleifera	VIRGIN ISLANDS" DRUMSTICK	United States	5
TOT4977	oleifera	MA RUM	Thailand	5
TOT5028	oleifera	MA RUM	Thailand	5
TOT5077	oleifera	MA RUM	Thailand	5
TOT5114	oleifera	MA RUM KHAW NHEAW	Thailand	5
TOT5118	oleifera	MA RUM KHAW NHEAW	Thailand	5
TOT5392	oleifera	MA RUM	Thailand	5
TOT5831	oleifera		Thailand	5
TOT7268	oleifera	DAVAO MALUNGGAY	Philippines	5
TOT7269	oleifera	LA-MU E	India	5
TOT7270	oleifera	RCA MORINGA	Tanzania	5
TOT7271	oleifera	VIENTIANE PAK-IHUM	Lao People's Democratic Republic	5
TOT7272	oleifera	MA RUM C	Thailand	5
TOT8779	oleifera	DWARF MORINGA	India	5
TOT8780	oleifera	DRUMSTICK TREE P	India	5
TOT8782	oleifera	RCA MORINGA	Tanzania	5
TOT8784	oleifera	LA-MU W	Taiwan	5
TOT8785	oleifera	LA-MU S	Taiwan	5
TOT8787	oleifera	PHNOM-PENH	Cambodia	5
A-M	peregrina	.	.	28

Seeds were started in Anderson Dye flats in sunshine mix 4 aggregate plus professional growing media provided by the Penn State University. The experiment was conducted for 22 weeks between the months of April and September. Greenhouse temperature was kept between 27°C and 30°C. There was no supplemental light provided to increase photosynthesis or day length. Treatments were assigned randomly to each location on the greenhouse bench. A map of the treatment layout can be viewed in Figure 1. Seeds were watered every other day with tap water and germination was recorded. Seedlings were transplanted after six weeks of growing in Anderson dye flats. Plants were transferred into seven L plastic pots measuring 15 $^{7}/_{8}$ in. tall and four-six in. wide. Each treatment number was sub-labelled A-E, with each letter representing a different replicate. *M. peregrina* plants were labelled A-M. Transplant day indicated day 0 of the experiment. On this day, number of leaves, length of roots and shoots (in.), pest presence of 0 to 20 individual insects (0-20), fresh weight in grams and other notable characteristics were recorded. Plants were fertilized with two tsp. Osmocote® at week two and 12 of the experiment. Plant height (in.) was recorded tri-weekly. Tri-weekly pest incidence quantification surveyed the entire plant for insects. Counting stopped when 20 individuals were observed, regardless of how many insects were present. Pest severity was rated tri-weekly on a zero-four scale with zero= no pest damage, one= 1-25% pest damage, two= 26-50% pest damage, three= 51-75% pest damage, and four= 76-100% pest damage. Other observations such as abnormal growth, or flower absence/presence were also noted. Any plant containing 75% or more dead tissue and a dead apical meristem was noted and discarded. At harvest time, leaves were separated from stems and leaf and stem dry weights (g) were recorded.

5392B	4977D	8779C	5831D
4880D	5392A	7271A	7268E
8785E	5028E	7268D	7270D
7268C	5077B	8782A	7271C
5028A	8779B	5114B	5831B

8785C	8780B	8782C
I	7272B	B
4880B	8784A	5831E
4100B	7271D	G

N

W **E**

S

7271B	5028C	7270E
C	4100C	A
5077A	7270B	4977C
4880A	8782B	5114A

D	7272A	8784B	4977B
8780C	8784C	5118B	4100A
4880E	7268A	J	8787A
7269A	5077C	7271E	8780A
8785B	8785D	5114D	N

5831C	5831A	8785A
E	5028B	L
8784D	4977A	H
7270A	4880C	7269B

K	4100E	F	8779A
5028D	7269D	5392C	5392D
8779D	4100D	5077D	5118A
5114C	7270C	7268B	8782D
7269C	M	4977E	8779E

Figure 1. Map of seed origin treatments with cardinal direction. Treatments A-M are replicates for *M. peregrina* treatments. The TOT was removed as a prefix for *M. oleifera* treatments.

Results

Mean germination and percent germination are displayed in Table 2. Mean germination time (MGT) was calculated for each treatment using Ellis and Roberts (1980) formula:

$$MGT = \frac{\sum (n\,T)}{\sum n}$$

In this formula, n= number of seeds newly germinated, T= hours from beginning of germination test, and ∑n= final germination. *M. peregrina* had the shortest mean germination time compared to the other treatments. Of the *M. oleifera*, TOT5831 had the shortest mean germination time. The longest mean germination time was observed in TOT5114. Many treatments exhibited 100% germination. Percent germination was 50 or less for TOT5118, TOT8787 and *M. peregrina*.

Table 2. Mean germination and percent germination for each treatment.

Treatment	**Mean germination time (days)**	**Germination (%)**
TOT4100	23.75	100
TOT4880	23.75	100
TOT4977	23.75	100
TOT5028	23.75	100
TOT5077	23.75	80
TOT5114	25.92	80
TOT5118	23.75	40
TOT5392	23.75	80
TOT5831	21.57	100
TOT7268	24.3	100
TOT7269	23.75	80
TOT7270	22.23	100
TOT7271	23.75	100
TOT7272	25.65	100
TOT8779	23.75	100
TOT8780	22.95	100
TOT8782	25	80
TOT8784	23.75	80
TOT8785	23.75	100
TOT8787	22.88	20
M. PEREGRINA	16.6	50

The fresh weight averages at transplant time are shown in Figure 2. TOT5028 and TOT7271 had the lowest fresh weights compared to the rest of the treatments. TOT8785 had the highest fresh weight with TOT5118 not far behind it. Many of the treatments died during transplant (data not shown). Root length did not vary much between treatments.

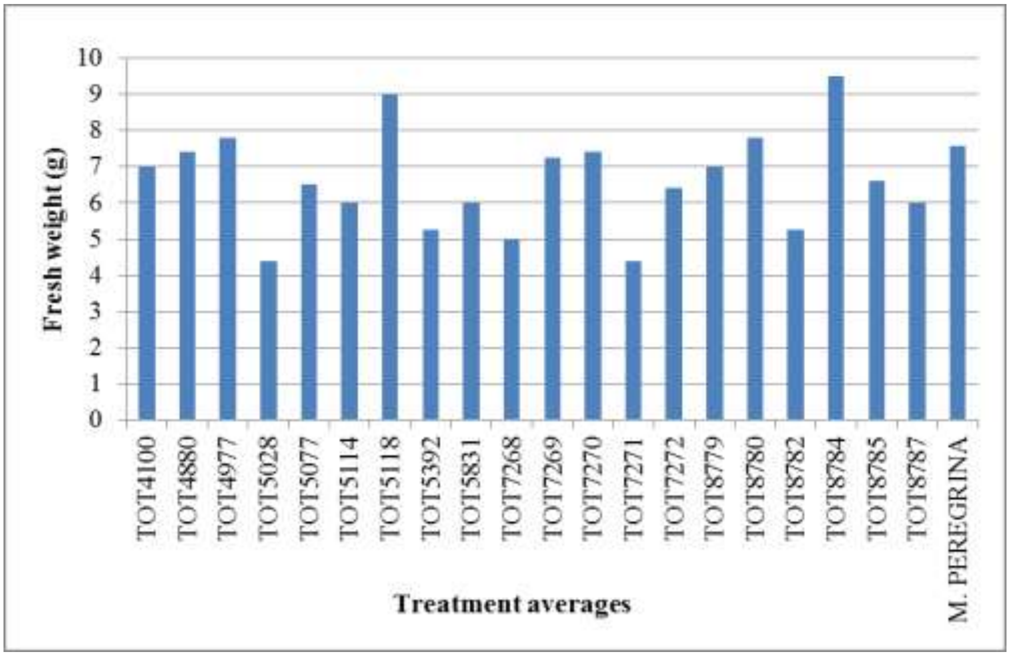

Figure 2. Average fresh weight comparison for all treatments.

TOT5114B distributed multiple shoots from a single seed (Figure 3). For the rest of the experiment, TOT5114B multiple shoots were labelled one and two, and the average of the two were taken. The third, smallest shoot shown in figure 3 did not survive the transplant.

Figure 3. TOT5114B multiple shoots per seed

Week 22 height averages per treatment are shown in Figure 4. TOT5118 was the shortest in height. TOT8779 was the tallest of all treatments.

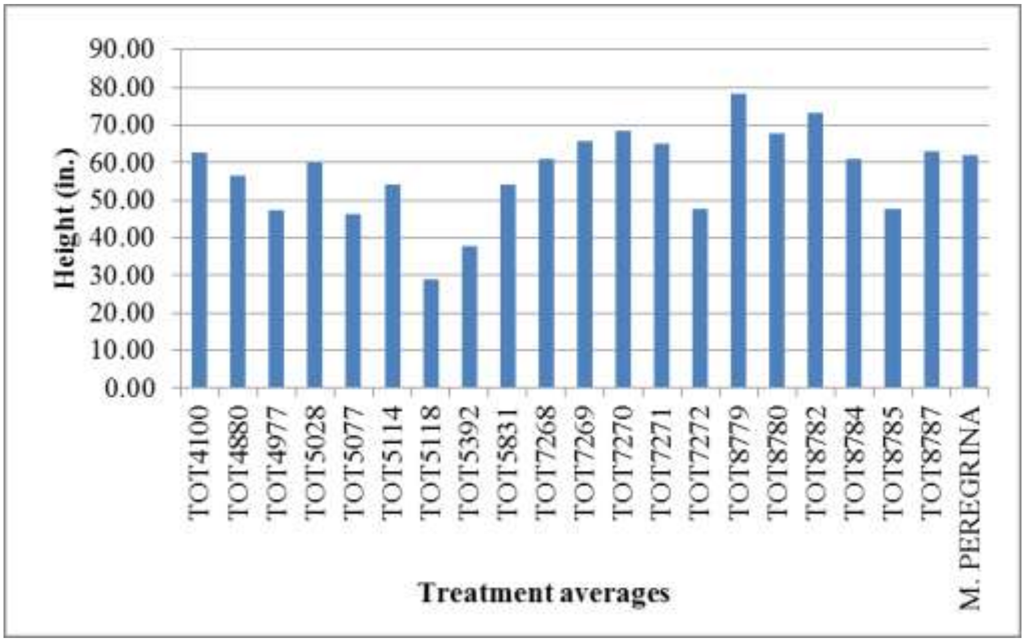

Figure 4. Average final height for each treatment

Figure 5 shows averages of leaf dry weight per treatment. TOT5118 had the smallest leaf dry weight while TOT5392 had the largest leaf dry weight. TOT8785, TOT8779,and TOT8787 had small leaf dry weights comparable to TOT5118. TOT4880, TOT7270, and TOT8782 had large leaf dry weights not much under TOT5392, the highest.

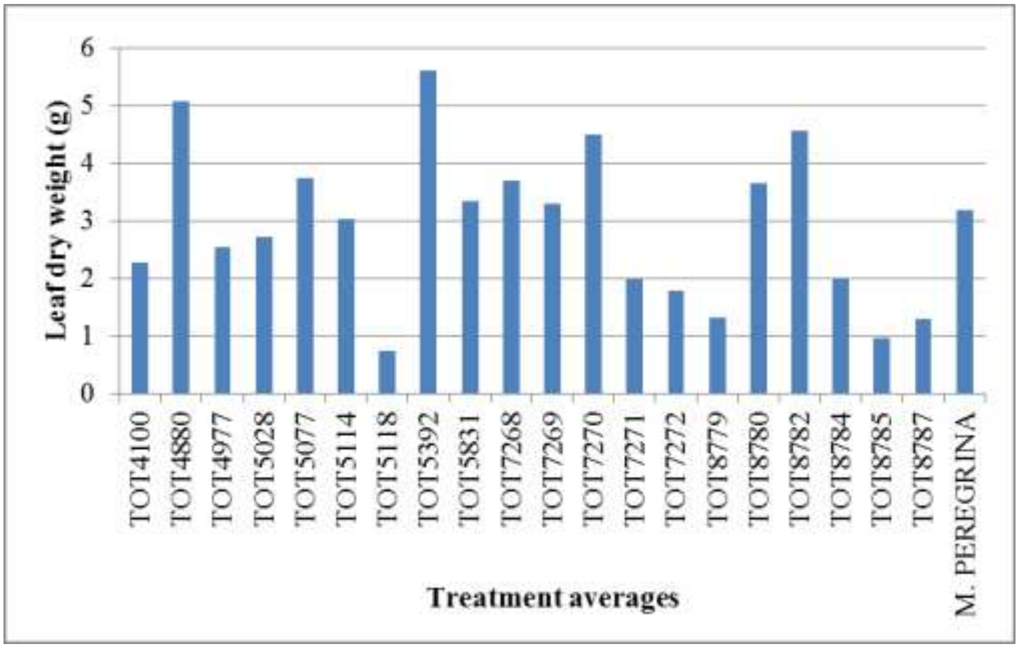

Figure 5. Average leaf dry weight for each treatment.

Figure 6 shows averages of shoot dry weight per treatment. TOT5392 had the smallest shoot dry weight and TOT8779 had the largest shoot dry weight. TOT8785 had a small shoot dry weight similar to TOT5392. Althought TOT8779 had the largest shoot dry weight, there were many other treatments comprable in weight (Figure 6.)

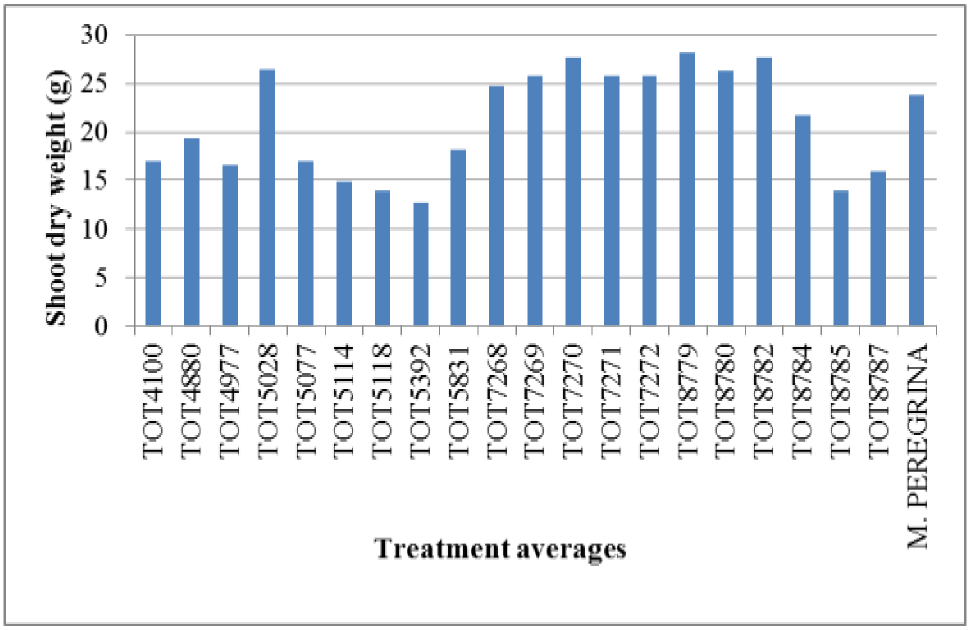

Figure 6. Average shoot dry weight per treatment.

Flowers were observed in some treatments between weeks 12 and 22 of the experiment. The treatments that produced flowers included TOT4100, TOT8779, TOT8782, and TOT8784. *M. peregrina* shoots were much more red in color than *M. oleifera*. Other noteworthy observations of *M. peregrina* compared to *M. oleifera* were that it tended to hold onto its bottom leaves longer whereas *M. oleifer*a shed them. *M. peregrina* leaves were often smaller in size compared to *M. oleifera*. Figure 7 shows *M. peregrina* characteristics compared to *M. oleifera* treatment TOT7271.

Figure 7. ***M. peregrina*** **and** ***M. oleifera*** **comparison on week 13. A=** ***M. peregrina*****; B=** ***M. oleifera*** **(TOT7271D)**

Discussion

Low germination rates could be caused by several reasons. *Moringa* seeds are only considered viable for 3-4 months of storage under ambient conditions (Pandey, 2011). Since the age of the seed used in this experiment is unknown, it is possible that that some of the seeds were older than others. In future studies, it is important to know the exact age of the seed one is starting. *Moringa* seeds are orthodox and do not have a dormancy period, so these factors did not likely contribute to the lack of seed germination (Pandey, 2011).

Fresh weight at transplant time was the only data recorded on transplant day that varied between treatments. Obtaining fresh weights was very stressful for the plant, with the greatest losses observed in *M. peregrina*. Therefore, *Moringa* species, especially *M. peregrina* may be particularly susceptible to transplant shock indicating that this may not be the best way to propagate them under commercialization. Length of root, height of shoot and pest incidence varied minimally between treatments on transplant day, which is why data was not shown. Additional tri-weekly growth parameter and pest data was also not highlighted because it was not relevant to the objectives of this preliminary experiment. The goal of the preliminary experiment was to identify growth parameter variation within *Moringa* ecotypes and species. Specifically, particular attention was paid to leaf dry weights and flower absence/presence since leaves and seeds are so important to the *Moringa* horticultural industry. Root dry weights were not taken because leaf biomass production was the cultivation of study.

Greenhouse bench placing probably could have had an impact on overall plant growth. The plants facing north were closest to the evaporative cooling system in the greenhouse, and therefore the temperature at this location was most likely cooler than the south facing side of the greenhouse. Some treatments may have also contributed to the lack of growth of other treatments due to competition by shading.

The most interesting observation from the dataset was that TOT5392, the treatment that had the highest leaf dry weight, also had the smallest shoot dry weight. This could be due to the habitat of this ecotype. Perhaps the shoots are thin and branching in order to produce a thick canopy of *Moringa* leaves. If this tree had more of a branching habit, it would explain why shoots remained small throughout the entirety of the experiment.

Chapter 3

Kaolin Experiment

Introduction

Although some horticultural research has been conducted with *Moringa*, there is little information available on control of *Moringa* pests. The following insects have been recorded to infest *Moringa oleifera; Nadiasa siva, Metanastria hyrtaca, Indarbela spp., Heliothis armigera, Aphis craccivora, Tetragonia siva, Eupterote molifera,Ceroplastodes cajani, Diaxenopsis apomecynoides, Gitona sp* (Sivagami,1968). This research explores environmentally sound techniques of handling pest problems like these on *Moringa*.

Pest management is one of the most important areas of research that must be studied if *Moringa* is going to be grown on a commercial scale. Much of the pest management that is conducted in the developing world is by the use of pesticides without the appropriate personal protective equipment (PPE) or without following recommended label rates. As these inappropriate practices continue to persist, new, safer pesticide products must be developed. Kaolin clay is an organic crop protectant that could serve as an appropriate substitution for the dangerous pesticides currently being used.

Kaolin clay works as a crop protectant by forming a barrier film on the plant surface tissue. This film is white, which confuses insect pests, encouraging them not to feed, lay their eggs on, or even reach plant tissue (Caldwell, 2013). This product also acts as an irritant if it comes in contact with the insect pest. Disease incidence and severity can also be lowered with kaolin clay application because the film creates an unsuitable environment for pathogens to live in. The barrier that kaolin provides can be beneficial in hot temperatures where plants are transpiring faster than they absorbing water in their roots. However, the barrier that kaolin provides may also reduce photosynthesis, therefore serving as a detriment to the plant. Kaolin clay is a naturally occurring product that results from weathering of aluminous minerals, such as feldspar, with kaolinite as its principal constituent. It is suspected that diluted, high clay soil will perform similarly to kaolin clay. If so, this finding could be very useful to farmers in developing countries that cannot afford high inputs in protecting their *Moringa* from pests.

Materials and Methods

Seeds were obtained from ECHO and Global Moringa. Plants were grown in a different greenhouse from the preliminary experiment, but under the same environmental conditions. Sticky card traps and biological control insects were applied to plants to keep them free of insect pests. Biological controls used were *Amblyseius cucumeris* for control of western flower thrips (*Frankliniella occidentalis*).

Moringa spp. trees were grown in 3.78 L pots and fertilized once with Osmocote®. Once trees were approximately one ft. in height the crop protectant Kaolin clay was applied for evaluation of protection against greenhouse insect pests. Plants were grown in the same greenhouse conditions previously described for the preliminary experiment. A pest population was already established on the *Moringa* grown for the preliminary experiment. In this study, *M. oleifera* free of pests and treated with half rate kaolin, full rate kaolin, double rate kaolin (2X) and control (water), were introduced into the pest infested greenhouse. These rates were decided upon to evaluate to determine the smallest amount of material possible for the maximum amount of control and also to evaluate if doubling the rate increases efficacy beyond the label rate.

Eight replications (plants) were used. The crop protectant was applied at two dates (August 4 and 6). These two dates were chosen because the first application did not successfully cover the product, so it was reapplied as soon as possible. Kaolin clay (Product Example Surround™ WP Crop Protectant, AgNova Technologies Pty Ltd (Melbourne, Australia) was mixed at the required rate with water in a five gallon bucket until completely incorporated into solution. Material was applied using a non-ionic surfactant at 1% v/v. Once the Kaolin clay wettable powder was completely incorporated into solution the plants were inverted and dipped into the solution. A pad of cardboard was placed over the plant stem and soil interface to prevent the plant and its soil from falling out of the pot during inversion. Plants were held in solution for approximately one minute to ensure coverage. The crop protectant Kaolin clay was applied twice to ensure adequate coverage of leafy foliage, as recommended by the label.

Ratings were taken at eight dates between August 4, 2014 and September 1, 2014: 1, 2, 3, 4, 6, 9, 11 and 30 days after treatment (DAT) based on availability of greenhouse access. Ratings of insect incidence were counted by surveying entire plant foliage visually. Insects were counted from 0 to 20 with 20 as the maximum regardless of how many insects were present. Pest severity was rated on the 0-4 scale described in this preliminary study. Plant height (in.) was measured from the soil line to the apical meristem. Aphid (Aphidoidea family) and two-spotted spider mite (*Tetranychus urticae*) incidence at 30 days was analyzed using one-way analysis of variance with means comparison using Fisher's protected least significant difference (LSD).

Results

All treatments were evaluated using the protocol established above. Figures are representative of mean insect counts by treatment over eight replicates observed throughout the duration of the experiment. Control treatment showed increases in aphid and spider mite insect incidences over the duration of the experiment (Figure 8). Aphid incidence increased (mean insects, 1 DAT 0 insects – 30 DAT 13 insects) over time. Insect population growth was positive until 5 DAT when aphid incidence decreased briefly before resuming positive growth at 6 DAT. Thrip incidence remained low (mean insects, 1 DAT 1 insect – 30 DAT 0 insects) over time. Thrip insect population did not appear to increase over the duration of the experiment. Spider mite incidence was low until insect population appeared to grow at 11 DAT (mean insects, 1

DAT 1 insect – 30 DAT 8 insects). Spider mite populations continued to grow for the duration of the experiment at 30 DAT.

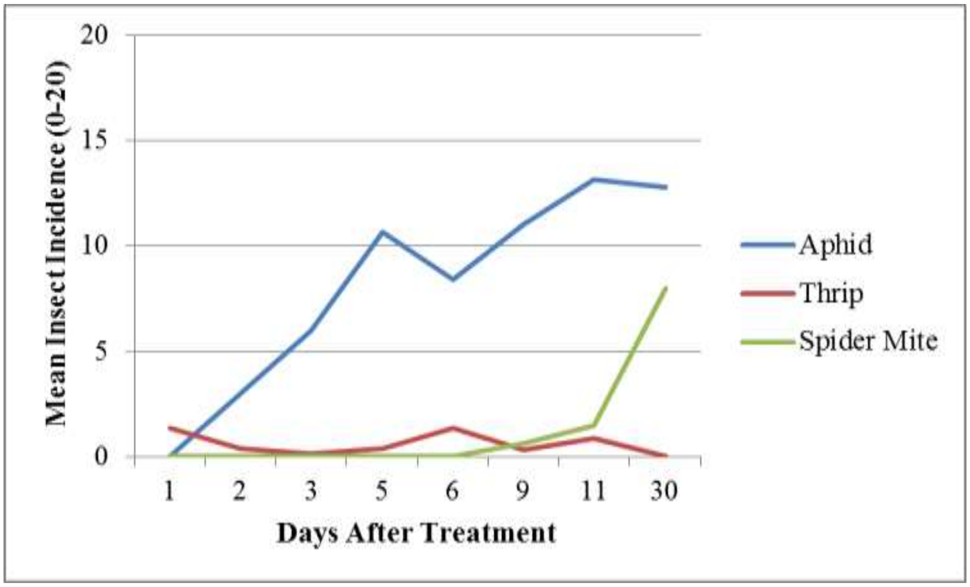

Figure 8. Insect incidence for control treatment.

Aphid incidence increased (mean insects, 1 DAT 2 insects – 30 DAT 17 insects) over time. Half-label rate of Kaolin clay treatments appeared to show increases in aphid and spider mite incidence over the duration of the experiment (Figure 9). At half-label Kaolin clay treatment, aphid insect incidence was 24% greater at 30 DAT than the control at 30 DAT. Insect population growth was positive until 5 DAT when aphid incidence decreased briefly before resuming positive growth at 6 DAT. Thrip incidence remained low (mean insects 1 DAT 4 insects – 30 DAT 0 insects) over time and thrip insect population did not appear to increase over the duration of the experiment. Spider mite incidence was low until insect population appeared to grow at 11 DAT (mean insects 1 DAT 0 insects – 30 DAT 12 insects). At half-label Kaolin clay treatment, spider mite insect incidence was 33% greater at 30 DAT than the control at 30 DAT.

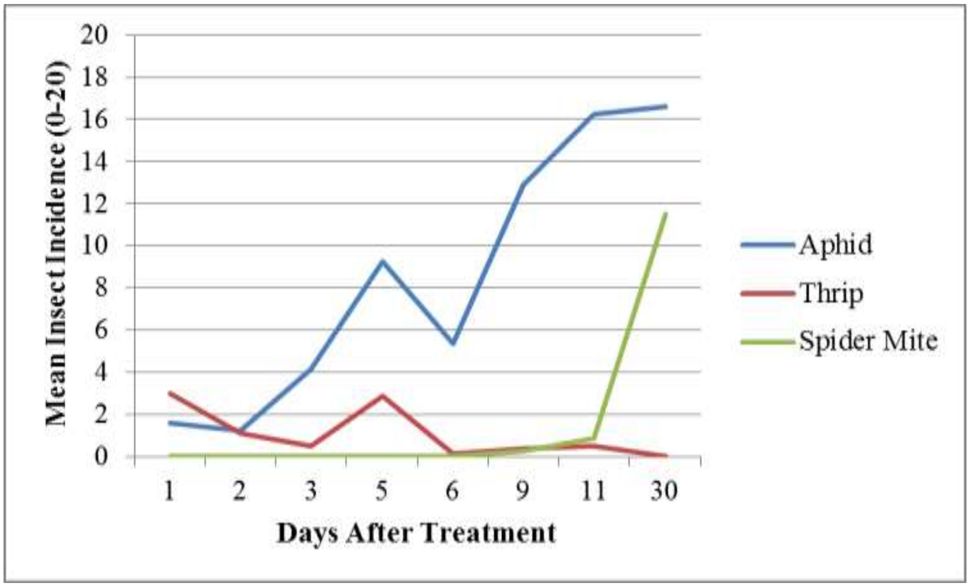

Figure 9. Insect Incidence at 0.5X Label Rate Kaolin Clay

Over the duration of the experiment, aphid and spider mite incidence appeared to increase when plants were treated with the full label rate of Kaolin clay (Figure 10). At full rate Kaolin clay treatment, aphid insect incidence was 38% greater at 30 DAT than the control at 30 DAT. Insect population growth was positive until 5 DAT when aphid insect incidence decreased briefly before resuming positive growth at 6 DAT. Thrip incidence remained low (mean insects 1 DAT 1 insect – 30 DAT 0 insects) over time. Thrip insect population did not appear to increase significantly over the duration of the experiment. Spider mite incidence was low until insect population appeared to grow at 9 DAT (mean insects 1 DAT 1 insect – 30 DAT 17 insects). At full rate Kaolin clay treatment, spider mite insect incidence was 113% greater at 30 DAT than the control at 30 DAT.

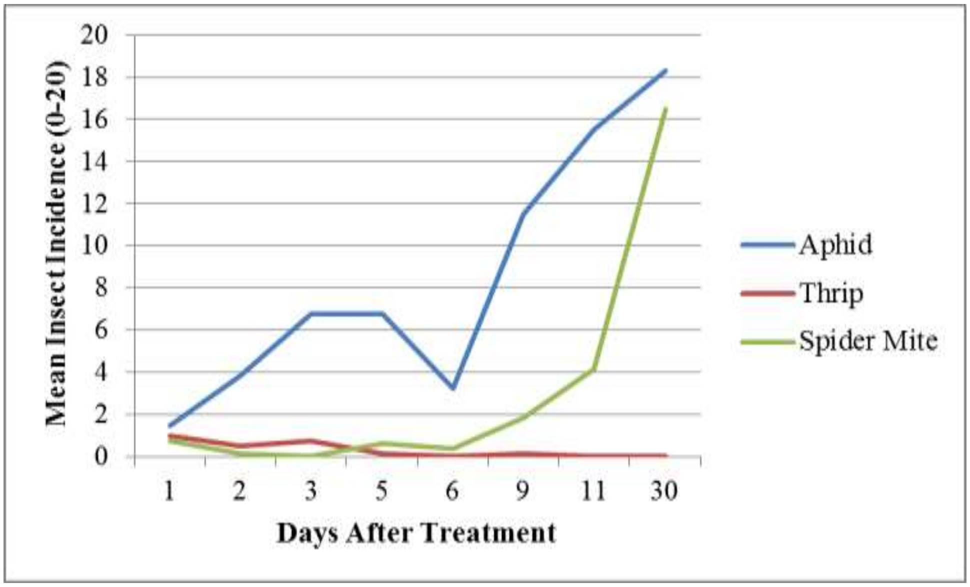

Figure 10. Insect Incidence at Label Rate Kaolin Clay

Two times the label rate of Kaolin clay treatments appeared to show increases in aphid and spider mite incidence over the duration of the experiment (Figure 11). At 2X label rate Kaolin clay treatment, aphid insect incidence was 23% greater at 30 DAT than the control at 30 DAT. Insect population growth was positive until 5 DAT when aphid insect incidence decreased briefly before resuming positive growth at 6 DAT. Thrip incidence appeared to decrease following treatment (mean insects, 1 DAT 4 insects – 30 DAT 0 insects) and disappear for the duration of the experiment. Thrip insect population did not appear to increase significantly after treatment. Spider mite incidence was low until insect population appeared to grow at 11 DAT (mean insects 1 DAT 0 insects – 30 DAT 10 insects). At 2X rate Kaolin clay treatment, spider mite insect incidence was 20% greater at 30 DAT then the control treatment at 30 DAT. Plant height, pest severity, shoot dry weight, and leaf dry weight did not vary significantly between treatments (data not shown).

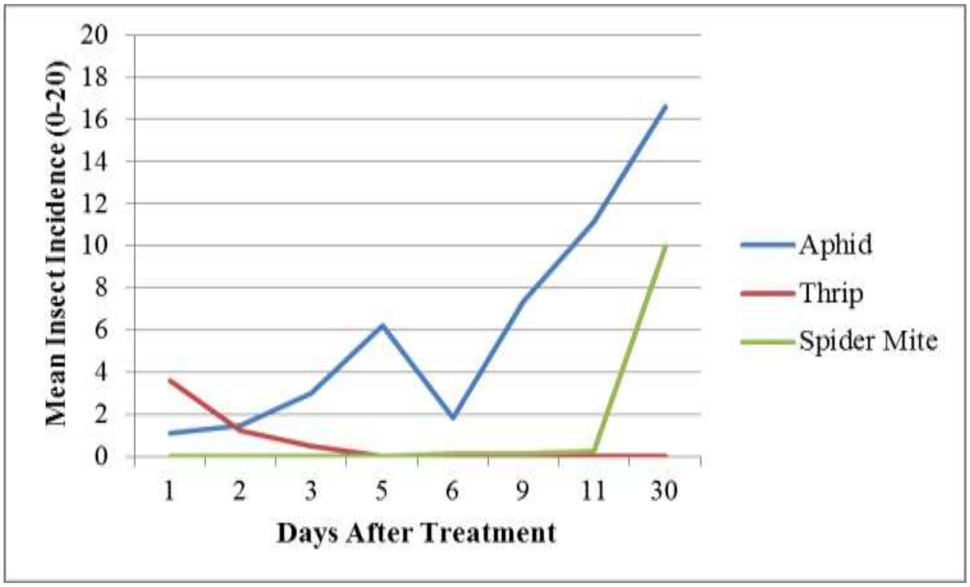

Figure 11. Insect Incidence at 2X Label Rate Kaolin Clay

A one-way analysis of variance with means comparison using Fisher's protected LSD was not performed for thrips on day 30 since there were no thrips recorded. Analysis of variance *p-value* shows that aphid incidence was not significant at 95% confidence on day 30. Table 3 shows that there are not significant effects of treatment rate on aphid incidence.

Table 3. Comparison of treatments on aphid incidence at day 30 using means compared with fisher's protected LSD (p = 0.517). Incidence with same letter following mean # sample are not significant.

Treatment	Incidence (Mean #/Sample)
Half Rate	16.6 a
2X Rate	16.6 a
Control	12.8 a
Label Rate	13.8 a

Analysis of variance *p-value* shows that spider mite incidence was not significant at 95% confidence on day 30. Table 4 shows that there are not significant effects of treatment rate on spider mite incidence.

Table 4. Comparison of treatments on spider mite incidence at day 30 using means compared with fisher's protected LSD (*p* = 0.132). Incidence with same letter following mean # sample are not significant.

Treatment	Incidence (Mean #/Sample)
Half Rate	11.5 a
2X Rate	10.0 ab
Control	8 ab
Label Rate	16.5 b

Two applications of each treatment were applied in this study since one application did not provide sufficient coverage. Dissecting microscope images of each treatment leaf surface are shown in figure 12.

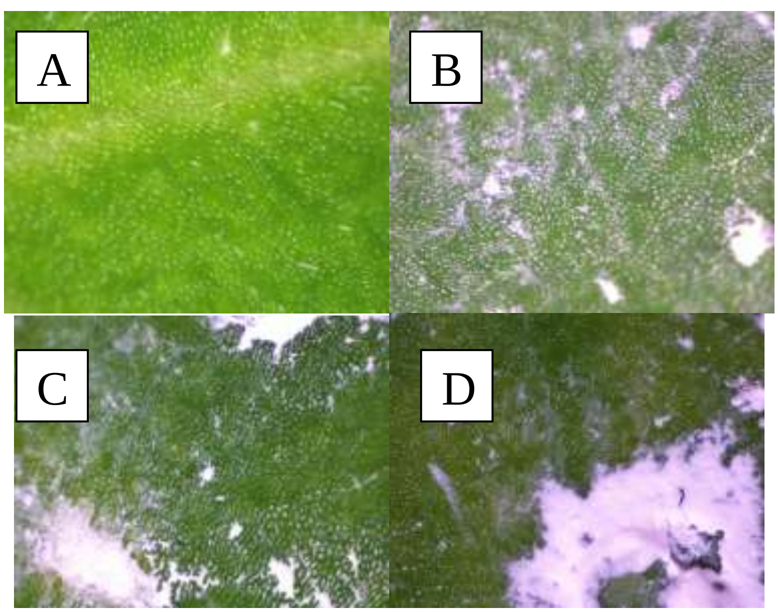

Figure 12. Microscope imagery of treatments on leaf surface. A= Control; B= 0.5 kaolin rate; C= full kaolin rate; D= 2X kaolin rate

Discussion

Kaolin clay is a common material used for plant protection from insect pests. Kaolin clay forms a protective barrier around the plant leaves, meristems, shoots and stems that insects are either unable or unwilling to penetrate to feed on the plant. Kaolin clay has broad-spectrum properties that protect the plant from many types of insect pests (Caldwell, 2013). The plant is still able to exchange gases through stomata through the clay barrier (Caldwell, 2013). Additionally, the plant is still able to photosynthesize through the clay barrier. This is consistent with this experiment because plant height, leaf dry weight and shoot dry weight of kaolin treatments were not significantly different than the control treatments .

Moringa is a unique plant in that the leaves are hydrophobic. Due to tiny hairs and a waxy coating on the *Moringa* cuticle, water is held on the leaf surface at extreme tension and will not readily adhere to the leaf surface (Ramachandran, 1980). Water actually rolls directly off the plant foliage. Because of this physical property of *Moringa*, the kaolin clay spray application did not adhere to the leaves or create adequate coverage (Figure 12). As a result, the plants were instead immersed in kaolin clay solution to apply the material more effectively. It took two applications to see full coverage of the plants foliage by the clay. However, the kaolin product must be tested with other types of surfactants to use on hydrophobic plants like *Moringa* in the future. A better understanding of the leaf surface environment of *Moringa* is critical for commercialization in the future.

Insect populations were similar throughout the duration of the experiment for all conditions. This may be due to high insect populations in the greenhouse where the study took place. Aphid populations appeared to decrease and rebound halfway through the trial for all treatments. This was due to the second application of crop protectant material. On the date of the second application, the aphids were momentarily subdued by immersion in water and the fresh crop protectant application. As a result, aphid populations appeared to decrease before increasing again for the rest of the experiment. Thrip populations remained low throughout the duration of the experiment for all treatments, which might be attributed to a low pest population of thrips in the greenhouse section at this time. Spider mite populations did not appear in the trial until 9-11 DAT. This may be due to the fact that they are less mobile compared to thrips and aphids. The half rate was significantly lower for spider mite incidence compared to the label rate, indicating that low rates may provide the same protection (Table 4).

Conclusion

In conclusion, experiments performed in the greenhouse were adequate in learning more about the horticultural requirements of *Moringa*. Preliminary experiments were adequate at determining *Moringa* growth characteristics and differences among ecotypes. Although kaolin did not serve as an appropriate product to use on *Moringa* without a surfactant, this study did identify the exceptional properties of the *Moringa* leaf surface. This information is critical to spread if the commercialization of *Moringa* is going to exist. With all the wonderful properties that *Moringa* has, horticultural research must advance its commercialization forward if we are ever going to be able to feed the world.

BIBLIOGRAPHY

Caldwell, B., Sideman, E., Seaman, A., Shelton, A., Smart, C. 2013. Resource guide for organic insect and disease management, 2nd ed. Cornell University, New York. Print.

Ellis, R.H. and Roberts, E.H. 1980. Towards a rational basis for testing seed quality. Seed Production, London. 605-635.

Nature, 2010. How to feed a hungry world. Nature 466 (7306): 531-532.

Palada, M.C. 1996. *Moringa* (*Moringa oleifera* Lam.): A versatile tree crop with horticultural potential in the subtropical United States. HortScience 3:794-797.

Pandey, A. Pradheep, K., Gupta, R., Nayar, E., Bhandari, D.C. 2011. ‘Drumstick tree’ (*Moringa oleifera* Lam.): a multipurpose potential species in India. Genetic Resources and Crop Evolution 58 (3): 453-460.

Price, M.L. 2007. The *Moringa* tree. ECHO Technical Note. Retrieved 19 March, 2014 from http://chenetwork.org/files_pdf/Moringa.pdf.

Ramachandran, C., K.V. Peter, and P.K. Gopalakrishnan. 1980. Drumstick (*Moringa oleifera*): a multipurpose Indian vegetable. Economic Botany 34:276-283.

Sivagami, R., David, B. V. 1968. Some insect pests of *Moringa* (*Moringa oleifera* (Linn." in South India. South Indian Horticulture 16: 69-71.

ACADEMIC VITA

Jennie Diehl
873 Thomas Street
State College, PA 16803
jrd5407@psu.edu

EDUCATION

The Pennsylvania State University (PSU), University Park, PA
Bachelor of Science degree in Horticulture
Minors: Plant Pathology; Biology; Sustainable Leadership
Expected graduation: May 2014.

RESEARCH

Integrated pest management (IPM) techniques for *Moringa oleifera*, Fall 2013-present
In vitro propagation of shagbark hickory witches' brooms, Spring 2013
Field soil and compost correlations with black root rot disease of strawberry, Fall 2012
Microscopic identification of fir species at Penn State Mont Alto, Spring 2012
Compared preservation solutions added to cut paperwhite flowers, Spring 2012
Cross-bred field mustard plants based upon phenotypes, Spring 2011
Evaluated efficacy of organic insecticides on the brown marmorated stink bug, Fall 2011

EMPLOYMENT

Laboratory Assistant. PSU Plant Disease Clinic. University Park, PA, 04/2013-present
Daily microscopic identification and assessment of plant pathogens.
Running real-time PCR to detect and quantify *Colletotrichum acutatum*.
Extracting DNA for comparison of *Phomopsis* species on pepper (*Capsicum* sp.).
Conducting cultural, molecular, and serological tests to identify pathogen(s).

IPM Coordinator. PSU Greenhouses. University Park, PA, 08/2012-present
Deploying and rearing biological control insects.
Planning, assembling, and maintaining PSU's first aquaponics system.
Programming function of greenhouse climate control computers.
Daily scouting of teaching and research plants for insects, disease, and nutrient deficiencies.

Crew Leader. PSU Fruit Research and Extension Center. Biglerville, PA, 05-09/2011, 2012
Identified, photo documented, and evaluated plant pathogens.
Entered and analyzed field data in Excel spreadsheets.
Pruned, thinned, and harvested fruit crops.
Isolated *Venturia inequalis* spores for fungicide screening.

Arboretum Technician. PSU. Mont Alto, PA, 01/2011-05/2012
Maintained an accurate catalog of the arboretum.
Assisted in experimental hybrid chestnut (*Castanea* sp.) planting.
Researched ethnobotanical uses of plants, and revised taxonomic information.

VOLUNTEERING

Discovery Kids Space Center Garden, 11/2012 and 04/2013
Fulton Center for Sustainable Agriculture, Wilson College, 06-07/2012
The Source Farm EcoVillage, Jamaica, 03/2011
Colonel Denning State Park, 04/2010

LEADERSHIP

Treasurer, Penn State Center for Sustainability Community Garden Club, 2013
Organizing monthly workdays and workshops.
Installing pollinator garden.
Allocating and organizing funds for plot renewals and projects.