FINAL REPORT

NORTHAST REGION SARE

FARMER/GROWER GRANT PROGRAM

SARE PROJECT FNE02-443

PRODUCTION OF NUTRIENT ENHANCED COMPOST AND COMPOST TEA USING VERMICULTURE TECHNOLOGY

Submitted by:

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INTRODUCTION

There is an abundance of information detailing the production methods for compost and compost tea. Likewise, there has been much information generated with regards to the production of compost using earthworms (vermicomposting) in conjunction with microbes as the agents of decomposition. This research project focused on taking finished, nutrient-rich compost that was produced by conventional composting methods and inoculating it with earthworms (*Eisenia fetida*). It was hypothesized, that as the earthworm population grew within this very favorable food environment, the earthworms through their life activities of ingestion, digestion and excretion would further nutrient enhance the compost.

Vermiculture is the raising of earthworms under controlled conditions. This technology has not been extensively used or researched in the Northeast due to the unfavorable climatic conditions found in the region. Cool falls, cold to very cold winters and very cool springs are not environmental conditions that lend themselves to successful vermiculture agrosystems conducted outside. But in recent years, many farmers in the region have constructed heated and ventilated greenhouses that create favorable growing conditions for plants and mitigate the effects of the outside weather. This compost/vermiculture research was conducted in a greenhouse that created a favorable vermiculture environment and concurrently allowed the production of vegetable and flower transplants.

The primary objective of this research project was to create and test an on-farm hybrid composting agrosystem that makes use of microbes and earthworms in sequence to produce nutrient enhanced compost and compost tea. These products could then be used by organic, transitional and conventional farmers to produce transplants and potted plants with the same lush-look as plants grown with synthetically produced soluble nutrients. Another important objective of this applied research was to provide farmers with a cost effective and low input tool to help them grow the visually appealing plants that consumers have come to expect.

METHODOLOGY

1. During March 2002, two production units were constructed in a small (14′ X 36′) greenhouse that is used to produce both flower and vegetable transplants. The greenhouse is heated with a thermostatically controlled propane heater and is automatically ventilated. Production units measuring 20 feet long, 3 feet wide and 3 feet in height were constructed along the greenhouse walls leaving an aisle in between the units.

2. The production units were constructed using a series of cradles that support a suspended bin. The bins were made by suspending 2″X 4″ welded wire fencing that is 6 feet wide from the cradle rails and lining the fencing with 6-mil plastic greenhouse covering. The cradles were built from 2″X 6″ rough-cut lumber and placed 6.5 feet apart. Each unit was constructed using 4 cradles. The cradle rails were constructed from 2″X 6″rough-cut lumber. Please refer to the attached photographs at the end of this report for details.

3. In the beginning of April, these bins were filled with compost. The compost was purchased from Holiday Farm in Dalton, Massachusetts and is produced from a combination of manure and yard waste. The compost was unscreened (to leave more undigested organic matter and thus providing a better food source for the earthworms) and <u>completely</u> mixed so that a very homogeneous mixture was deposited in the bins. It is essential that both units contain the same compost at the beginning of the research. Prior to the introduction of the earthworms, compost samples were collected from both bins and analyzed by the University of Massachusetts Soil Laboratory to establish baseline results for nutrient content.

4. After the bins were filled with compost, seventeen pounds, approximately 17,000 *Eisenia fetida* (redworms or red wigglers) were purchased and introduced to only one of the two research bins (Unit A). Epigeic earthworms like *Eisenia fetida* live in the organic horizons of soils and ingest large amounts of litter. The other bin (Unit B) was not inoculated with earthworms and served as the control for these experiments.

5. Parameters that provide an ideal environment for the growth of the earthworm population were closely monitored on a daily basis throughout the life of the project. These growth factors included temperature, moisture, aeration, pH, diseases, predation and other biotic as well as abiotic factors that might limit population growth. Growth conditions were assessed daily and adjustments to the system made as needed. The earthworms enjoyed the same growing conditions as the plants that were grown above them. During the heat of the summer, the units were shaded with wooden pallets and plastic shade cloth on the inside. Plastic shade cloth material was installed on the outside over the greenhouse plastic to further shade the inside of the house. The ventilating fan was set at 80 degrees Fahrenheit and allowed to remain in the on position for the entire summer. During most of the Summer of 2002, the shade and automatic ventilation system kept the compost at a favorable temperature range (55 – 80 degrees Fahrenheit), which is needed for optimum earthworm activity.

6. A perforated liquid collecting pipe was installed at the bottom of each production unit. The bins were constructed so that the entire bin sloped 1-2 degrees toward the liquid collecting end. Irrigation water and other water added to the system percolated downward through the compost and were eventually captured by the perforated collecting pipe. Liquids were held in the pipe with a stopper placed at the open end of the pipe. At the collecting end of the pipe, liquids were drawn for analysis. Refer to the attached photographic section for details.

7. Once the production units were constructed and operational, growing benches were placed over these units and seedlings in a variety of growing containers were grown on the benches. The water needs of the earthworms were easily satisfied when the plants above the bins were watered. If the earthworms required more water than was received through the irrigation of the plants, then supplemental water was added to the system by purposefully watering the bins. When less or no water was needed in the bins, the plants on the benches were carefully watered so as to not add water to the compost. Moisture content of the compost was closely monitored with a moisture meter and adjusted as needed so that favorable conditions for worm growth and reproduction were maintained. The transplant seedlings were grown in a compost-based growing mixture and did not receive added nutrients from external sources. This eliminated the possibility of introducing alien nutrients to the compost in the bins.

8. The two research bins received identical management during the 6-month project research period (April 1, 2002 to October 1, 2002). The variable that was examined in this research was the work of the earthworms.

9. Approximately every two weeks, compost samples were taken from both units and sent to the University of Massachusetts Soil Laboratory for analysis. Compost samples were taken from the upper 6-8 inches of compost. A sample was taken from each of the three sections that make up a unit then blended together to yield a representative sample that was then sent for analysis. The compost tea created in both Unit A and Unit B was collected on the same schedule as the compost and sent to the University of Massachusetts. Refer to the attached photographs for details.

RESULTS AND DISCUSSION

After the experimental units (Unit A and Unit B) were constructed, approximately 17,000 (17 pounds) *Eisenia fetid*a (earthworms) were introduced to Unit A. Unit B did not receive *Eisenia fetida* and functioned as the control for this research. Both units were constructed to the same dimensions with the same materials and both were filled with the same compost. The work of the earthworms placed in Unit A was the only variable to be measured during this research. After the research apparatus was established, daily inspections were conducted to make sure the environmental conditions that are necessary for the growth of earthworms were maintained.

The collection on compost samples began on April 9, 2002 and the first tea samples were collected on April 23, 2002. The first compost samples established a baseline for compost nutrient levels in both Unit A and Unit B. Tea samples from both units were collected two week after the baseline compost samples to give the earthworms time to alter the compost and produce baseline readings for the tea samples. Compost and tea samples were taken from both Unit A and Unit B on approximately two-week intervals. These samples were hand delivered to the University of Massachusetts Soil Lab. on the same day as the sampling was conducted. The soil lab. analyzed the compost samples from Unit A and Unit B along with the tea samples from both units. Nitrate-N, phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) concentrations were determined for each sample. Standard compost tests were conducted but the five nutrients previously mentioned were the only parameters used for comparison. The idea was to ascertain whether or not the earthworms could enhance the nutrient levels in both the compost and tea for the five tested nutrients. If the experimental setup for Unit A and Unit B are identical then it can be assumed that bioaccumulation and/or the release of nutrients by the microbe populations in each unit should be same under the same set of environmental conditions. The compost was finished and stable but even though the compost did not heat up, more than likely, microbial decomposition continued at a reduced rate.

As with all research that is conducted for the first time and possibly after several attempts, there can be problems. There were two significant glitches that may have influenced the data. The first had to do with a leak that developed at the collection pipe outlet of Unit B. This leak was detected on June 15, 2002. The constant removal of tea by the continuous dripping at the liquid collecting end of Unit B resulted in having to add water to the system when tea samples were taken for analysis. Data collected prior to June 15 should not be influenced by the leak, but data compiled after that date may be compromised. The same apparatus setup in Unit A did not leak. In the future, I would use bathroom silica caulking to seal the interface between the collecting pipe and the plastic liner.

The second glitch came in the form of native earthworms that were volunteers in the compost. In Unit B (no redworms introduced), the native population by the end of the research (Sept. 2002) had exploded. These worms most certainly influenced the results of the later data readings through the concentration and/or release of nutrients. In the *Eisenia fetida* inoculated Unit A, the redworms appear to have successfully competed with the native species and held there population in check

Data Interpretation

Figures 1 through 5 depict in graph form the data compiled from the compost samples taken from Unit A and Unit B and analyzes for nutrient content. Figures 6 through 10 are graphs that illustrate the data compiled from the analysis of the tea that was created and collected in both units.

Compost Graph Analysis

Figure 1. – This graph compares the nitrate-N amounts found in the samples of compost in both Unit A (worms) and Unit B (control). After the 7/2 samples, the nitrate-N available in Unit A increased substantially. This increase could possibly reflect the activities of the earthworms on the compost at this stage of the experiment. Did the earthworm population need to increase to some critical number before significant nitrate-N enhancement began?

Figure 2. –Illustrates the phosphorus content of the compost from both units. The results indicate that both units contained approximately the same amounts of phosphorus through out the research. The earthworms appear to have little effect on phosphorus amounts.

Figure 3. – This graph illustrates the quick release of potassium in the compost early in the research. This is consistent with other research that points to the fact that potassium is physically broken down and does not need biological processes to facilitate its release. After 6/18, the values for potassium in the worm unit steadily increase indicating that the worms are having some effect on the availability of potassium at this stage in the research. After the 4/23 spike, the potassium levels in the control unit (Unit B) steadily decline for the remainder of the research.

Figure 4. – The calcium readings in the compost showed no significant differences between Unit A and Unit B. After 6/18 the calcium availability increases in both Units through 9/25.

Figure 5. – The magnesium results were very similar to calcium and phosphorus. There does not appear to be a clear difference between Unit A (worms) and the wormless Unit B.

Tea Graph Analysis

Figure 6. – This graph illustrates that a high concentration of nitrate-N in tea is available in the early samples and that the concentration steadily declines with time. Based on this data, the tea would supply ample amounts of nitrate-N for greenhouse use. In fact, further research would be needed to calculate dilution rates, as the amount of available nitrate-N is too high for practical use.

Figure 7. – The phosphorus in tea graph represents phosphorus' inability to easily be leached from the compost and that the earthworms appear to have little influence on making phosphorus available in the tea.

Figure 8. – The potassium in tea graph illustrates the influence that the earthworms had on the physical release of potassium into the leachate. The control unit shows little influence on the potassium concentrations through time.

Figure 9. – This graph depicts the calcium concentrations in tea during the research. The earthworms appear to have had an influence on the amount of calcium in the tea. In Unit A, the concentrations were high in the early and later stages of the testing. The control (Unit B) shows a slower, steadier availability of calcium with time.

Figure 10. – The magnesium in tea graph is very similar to the configuration of the calcium graph. The earthworm population appears to have influenced the availability of the magnesium in both the early and later stages of the research. The data collected from the control unit shows a slow, steady increase throughout the research.

General Data Observations

The data collected from the compost testing shows a definite and relatively rapid decrease in the 6/18 samples for phosphorus, potassium, calcium, and magnesium. I am not sure what accounts for this event but it may be temperature related. During that period it was very hot both inside and outside of the greenhouse. This heat wave resulted in the compost heating to 84 degrees Fahrenheit which was the highest compost temperature recorded during the research. The high temperature of the compost may have reduced the biological activities of the earthworms and as a consequence, reduced the availability of the nutrients in the 6/18 sample.

The potassium, calcium, and magnesium tea samples had a similar dramatic reduction in ppm with a two-week lag period behind the compost samples. This too may be heat dependent. Further research would be needed to explain these observations.

Compost data in the form of nutrient test values was compiled from April 9, 2002 until September 25, 2002. For the tea, nutrient data was collected from April 23, 2002 until September 25, 2002. This data was organized and represented in graph form to help with its interpretation. The graphs that accompany this report depict major nutrient concentrations in both the compost and compost tea at two-week intervals.

GRAPHS

Figure 1. - COMPOST

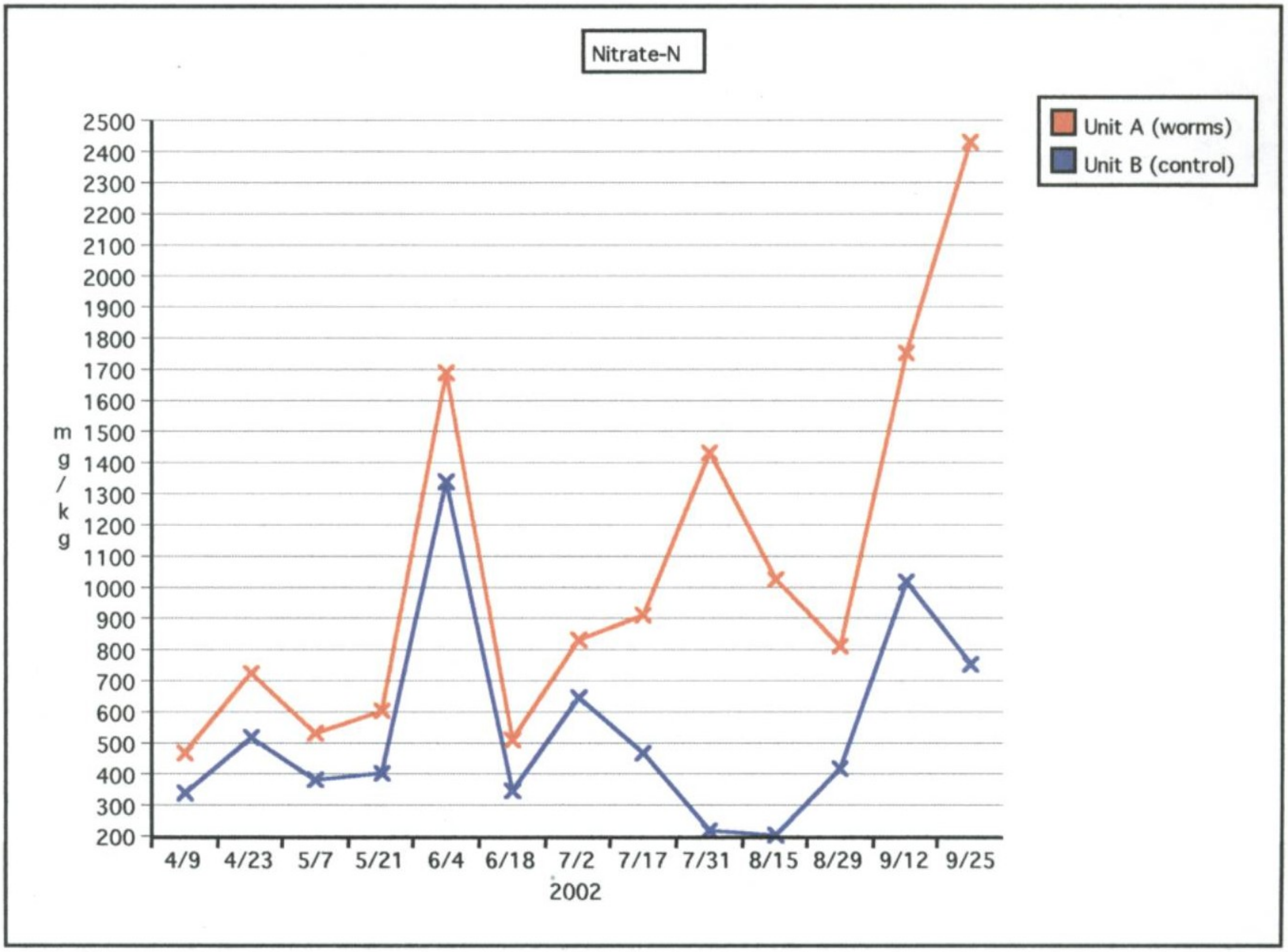


Figure 2. - COMPOST

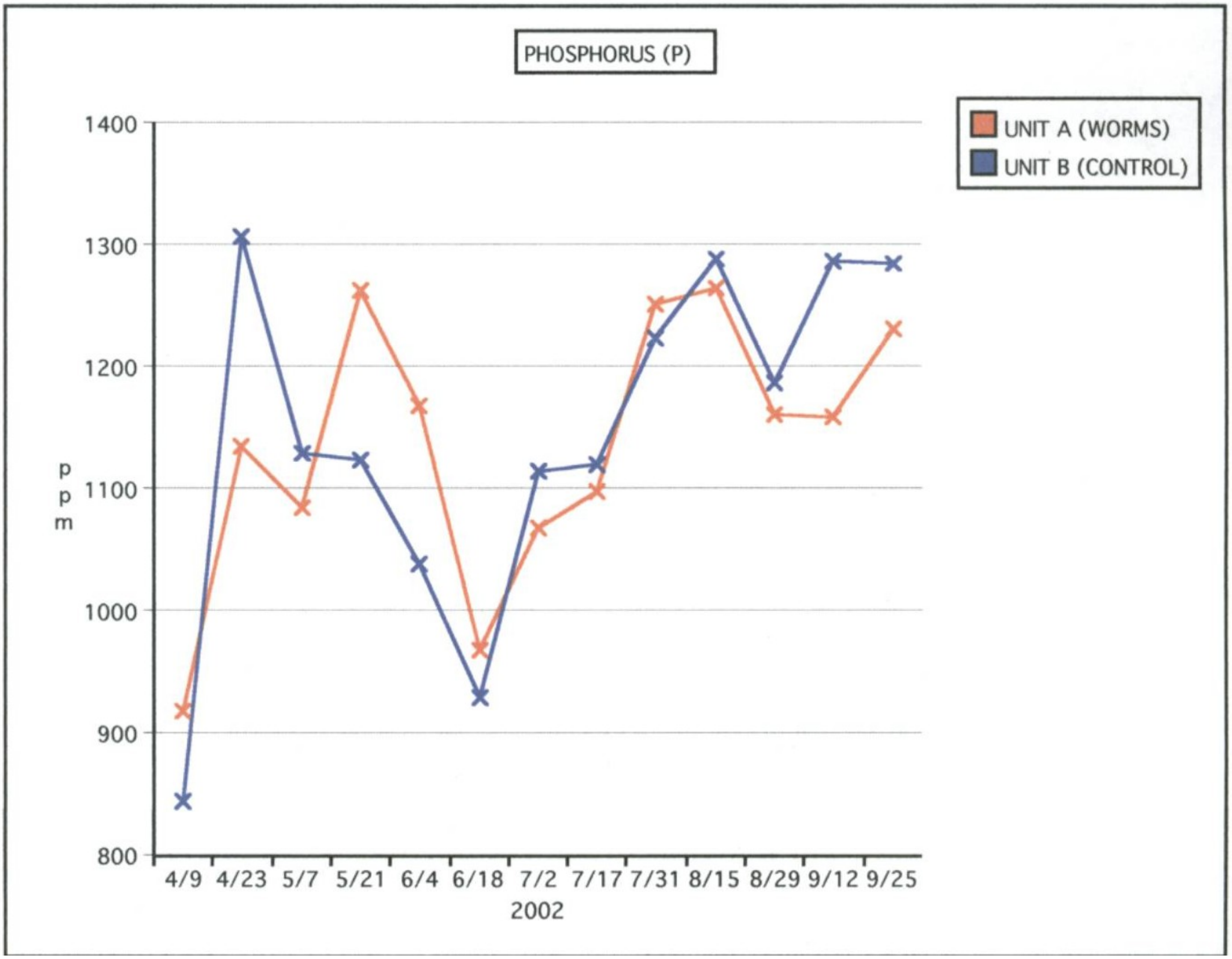


Figure 3. - COMPOST

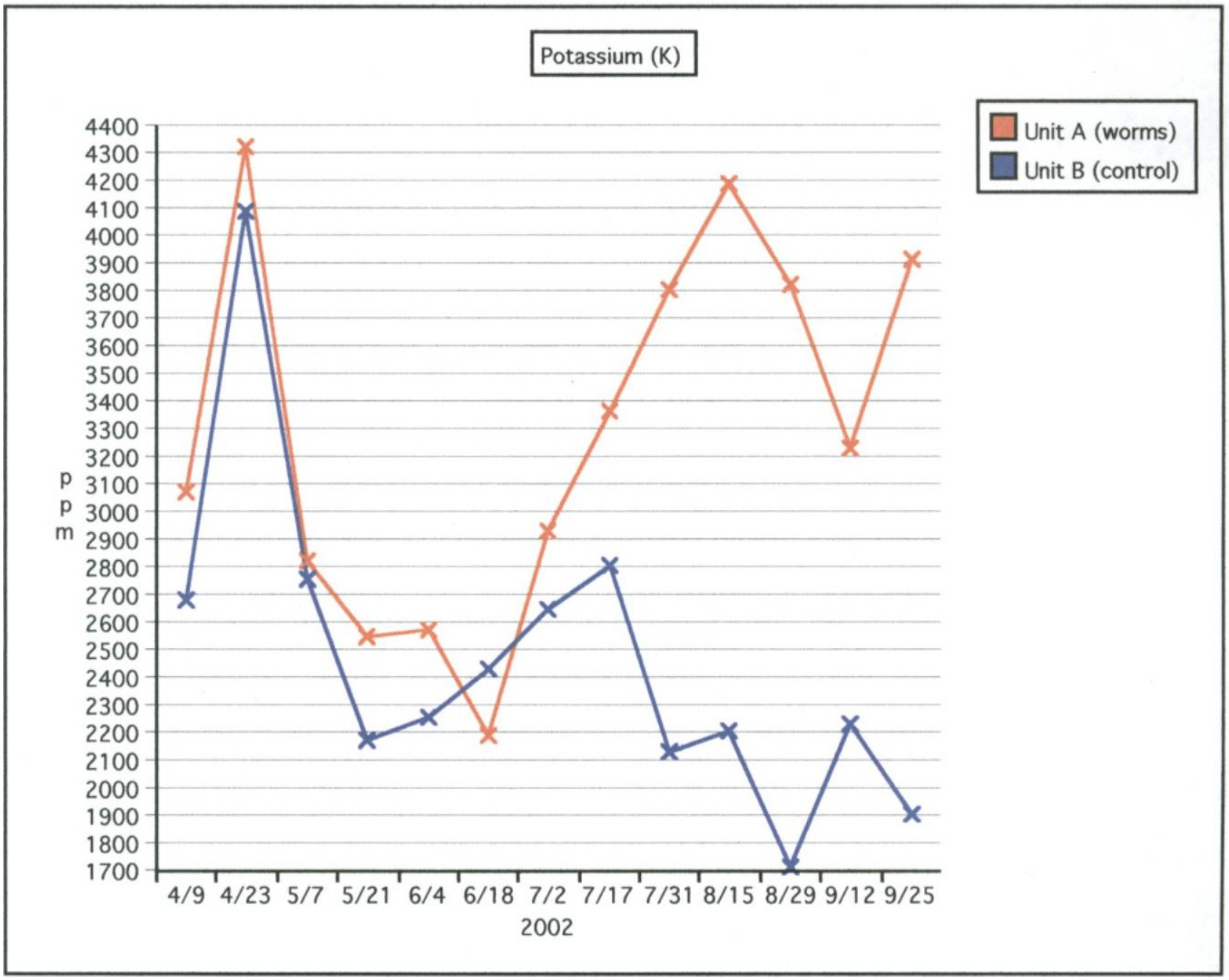


Figure 4. - COMPOST

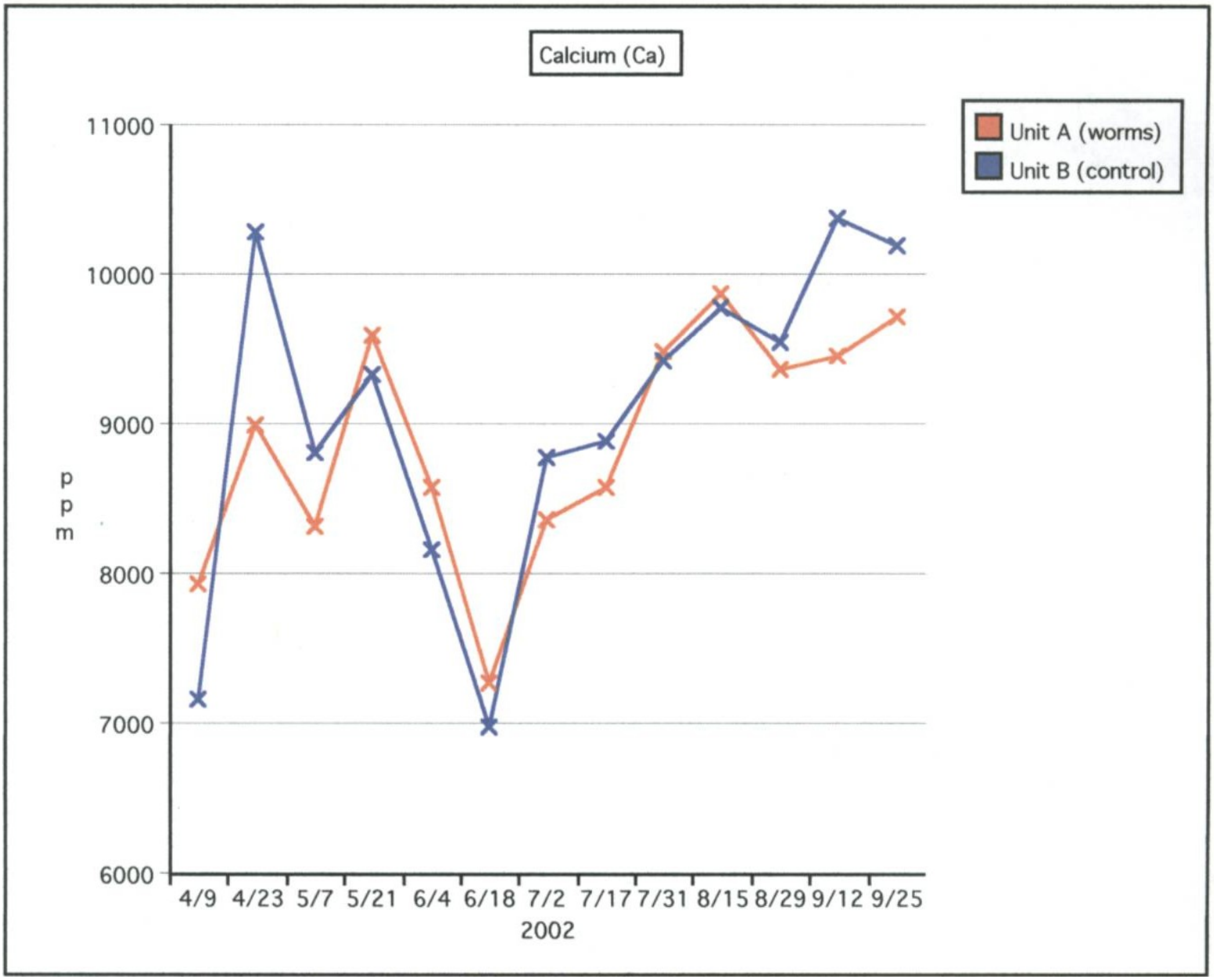


Figure 5. - COMPOST

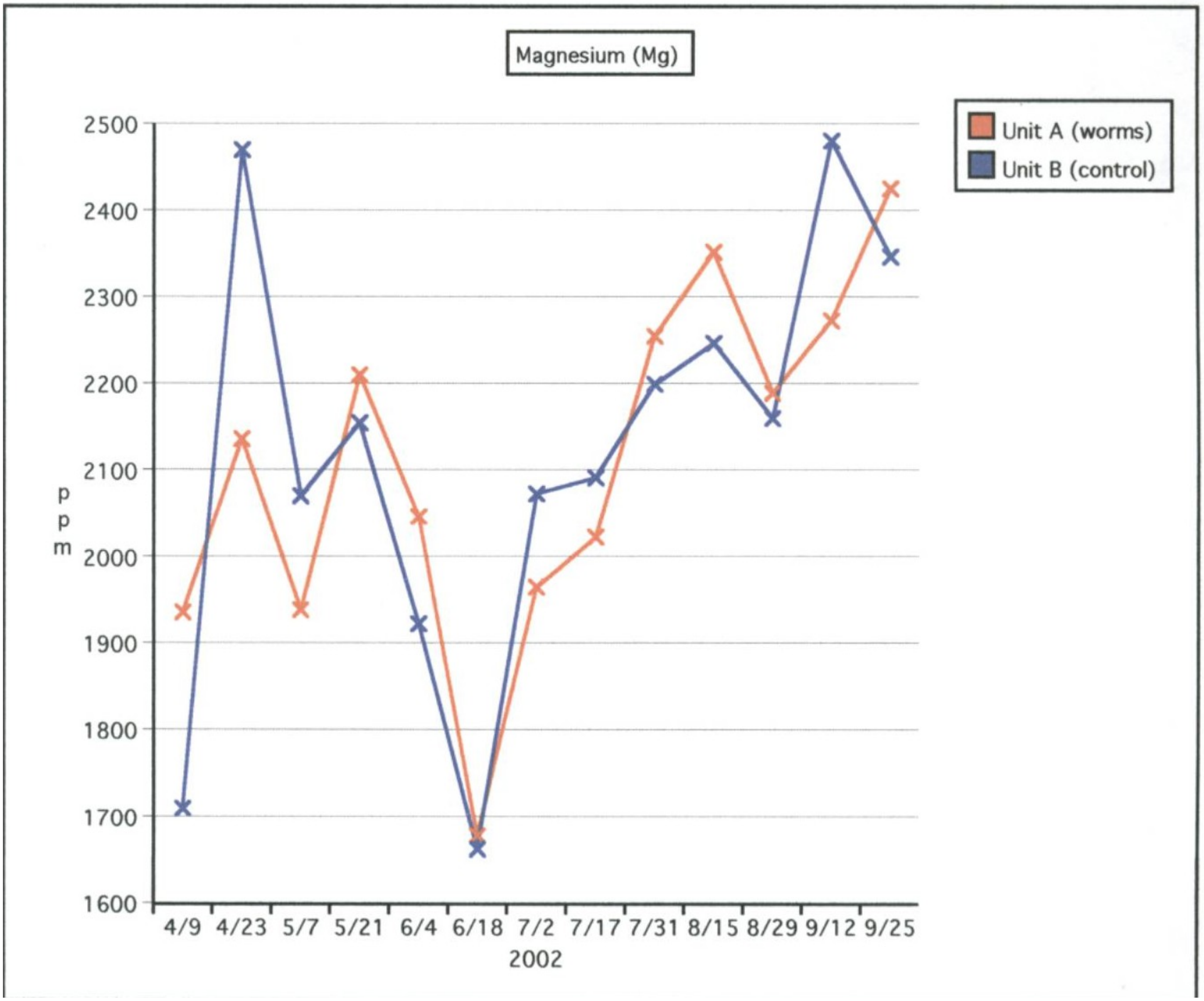


Figure 6. - TEA

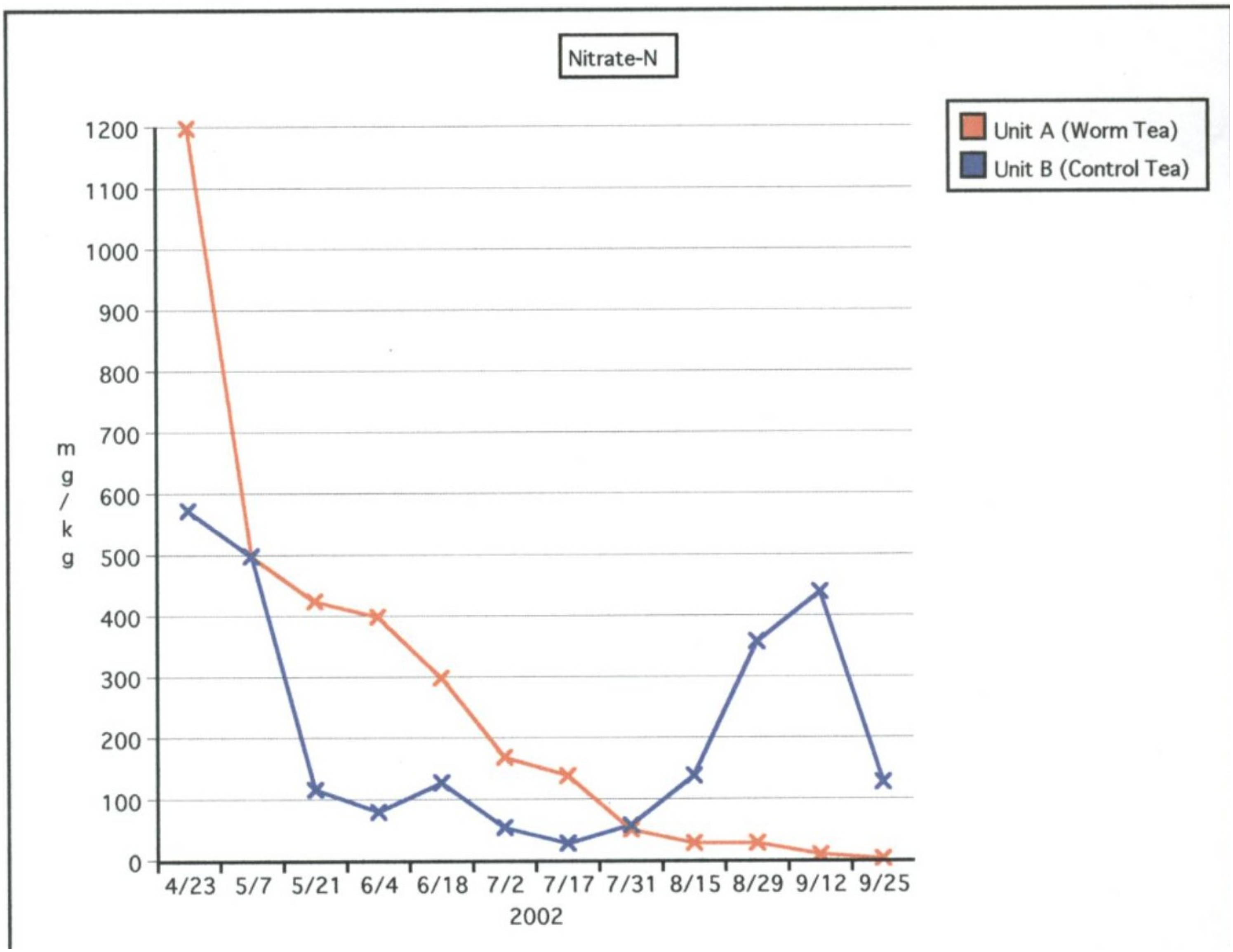
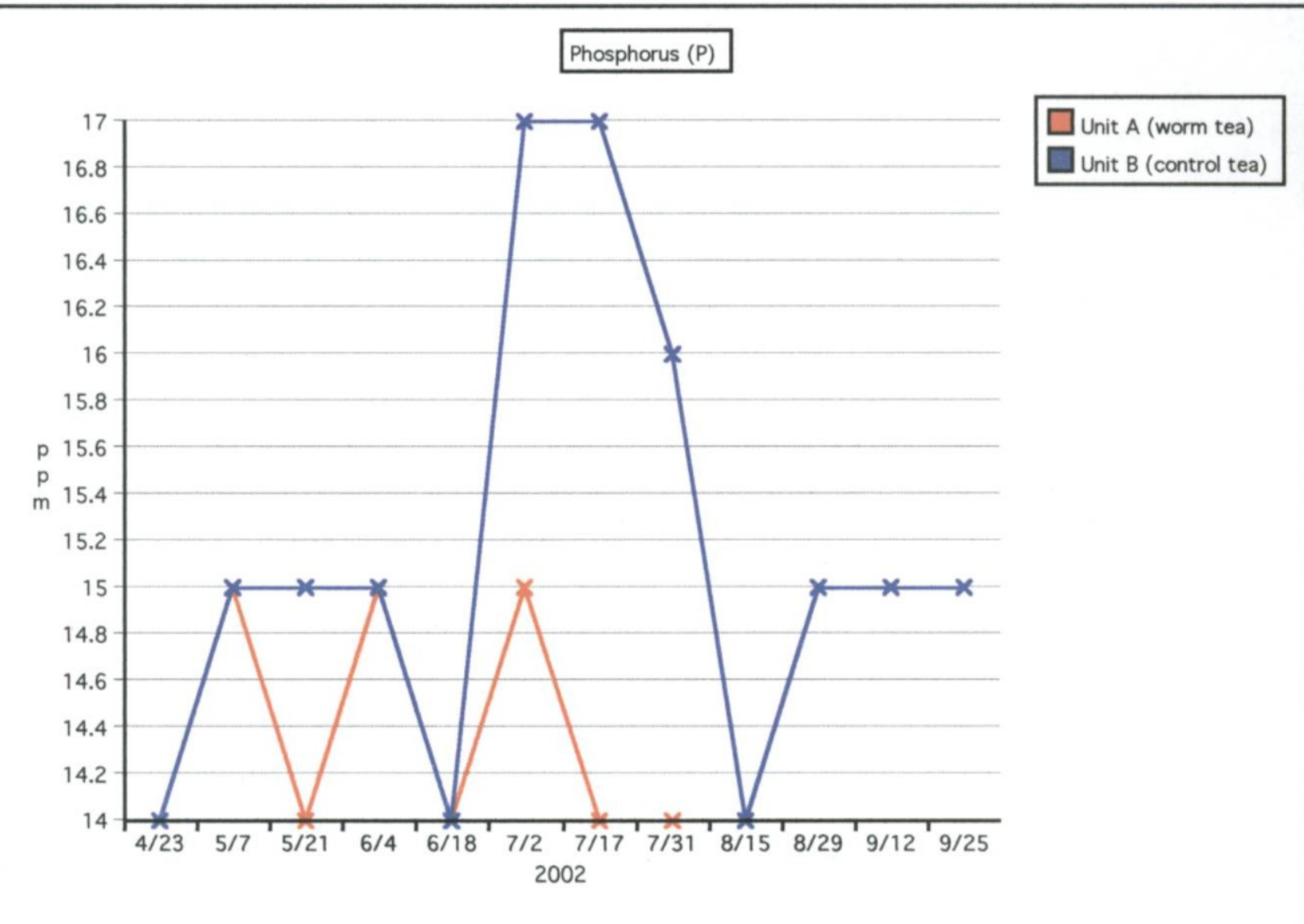

Nitrate-N
Unit A (Worm Tea)
Unit B (Control Tea)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
mg/kg
4/23
5/7
5/21
6/4
6/18
7/2
7/17
7/31
8/15
8/29
9/12
9/25
2002

Figure 7. - TEA



Phosphorus (P)
Unit A (worm tea)
Unit B (control tea)
ppm
17
16.8
16.6
16.4
16.2
16
15.8
15.6
15.4
15.2
15
14.8
14.6
14.4
14.2
14
4/23
5/7
5/21
6/4
6/18
7/2
7/17
7/31
8/15
8/29
9/12
9/25
2002

Figure 8. - TEA

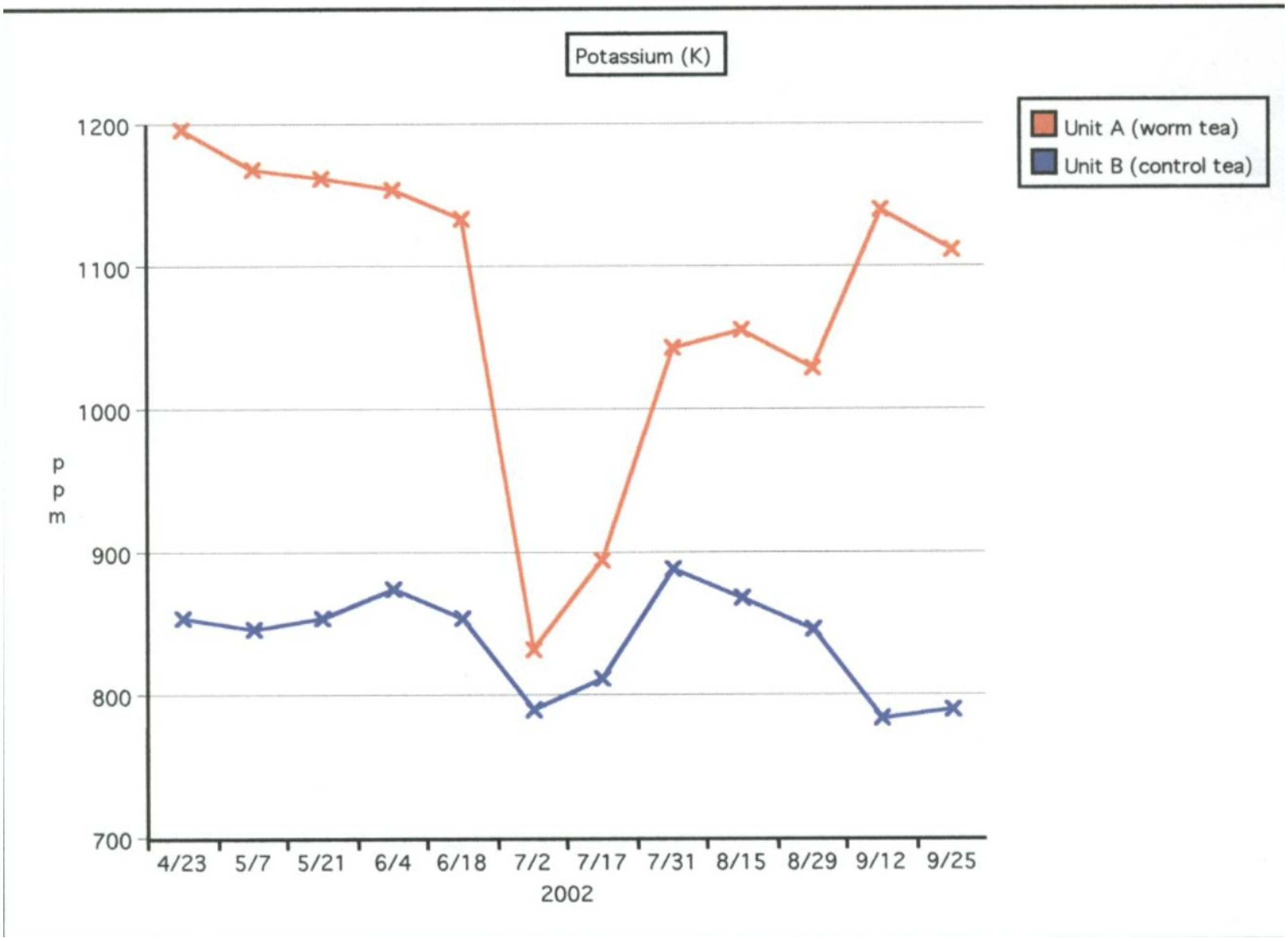

Potassium (K)
Unit A (worm tea)
Unit B (control tea)
1200
1100
1000
900
800
700
ppm
4/23
5/7
5/21
6/4
6/18
7/2
7/17
7/31
8/15
8/29
9/12
9/25
2002

Figure 9. - TEA

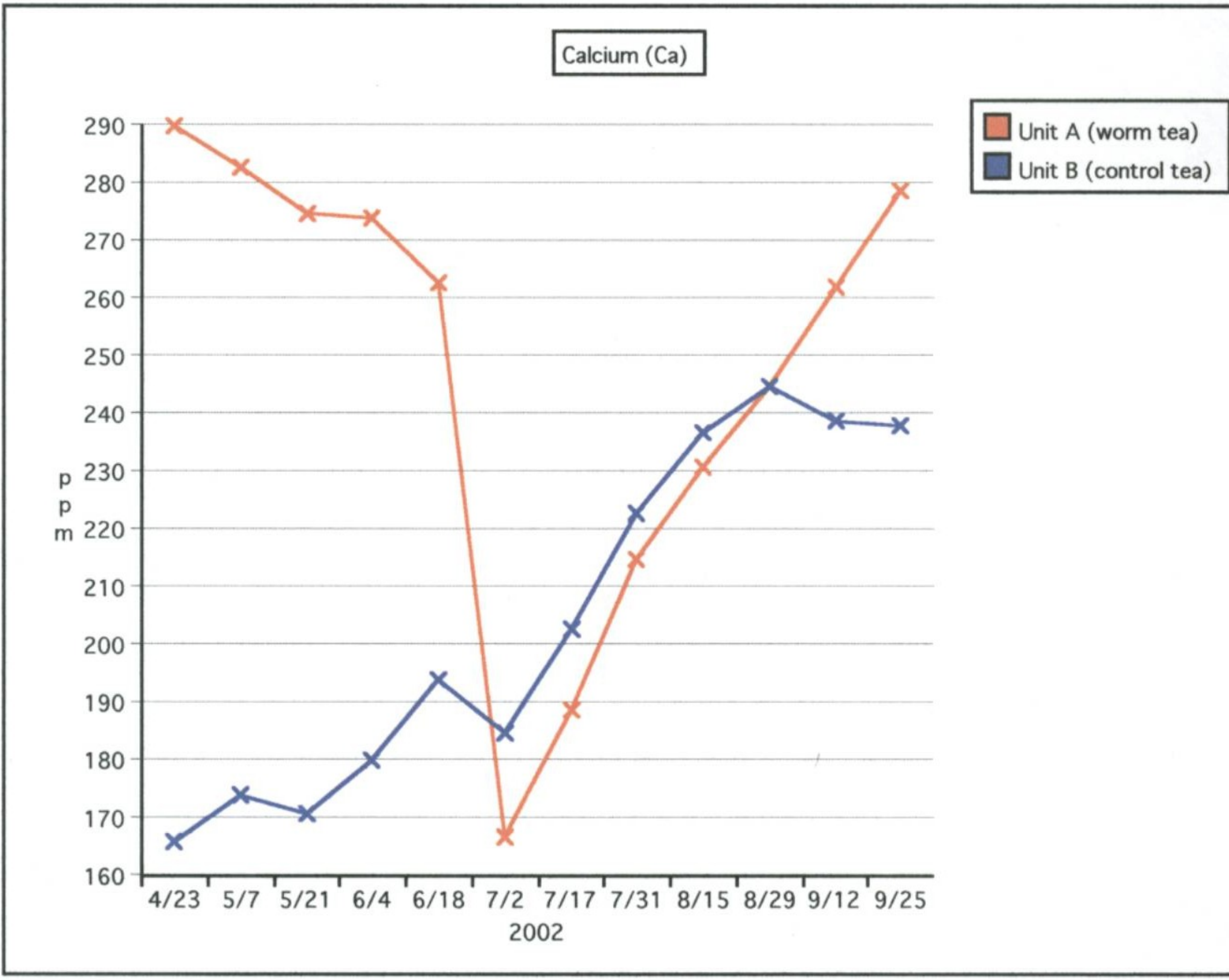
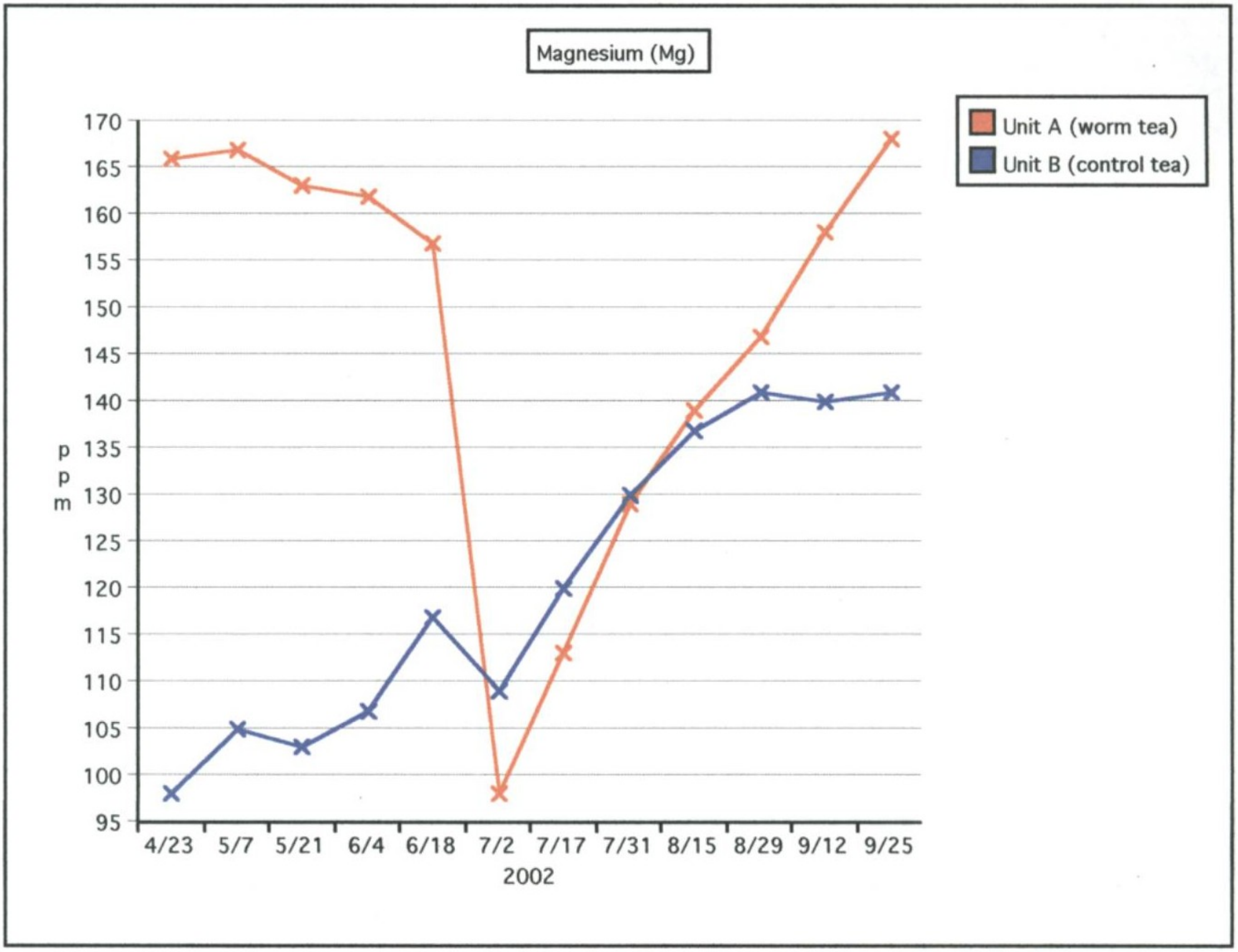

Calcium (Ca)
Unit A (worm tea)
Unit B (control tea)
ppm
290
280
270
260
250
240
230
220
210
200
190
180
170
160
4/23
5/7
5/21
6/4
6/18
7/2
7/17
7/31
8/15
8/29
9/12
9/25
2002

Figure 10. - TEA



RECOMMENDATIONS

When the earthworms were first released into Unit A, they quickly burrowed into the compost. That night, I inspected Unit A only to find that some of the earthworms were migrating out of the bin. I kept the greenhouse lights on at night for several nights to discourage their migrations. This procedure seemed to be effective.

Next time, I would build the production units to a height of 2.5 feet and make them 5 feet wide. This would make it easier to maintain the plants growing above the units and still provide a favorable vermiculture environment.

At the tea-collecting end of the both units, I would attach a non-perforated standpipe to the end of the perforated liquid collecting pipe. This would allow for the taking of tea without putting a hole in the plastic liner. This addition would significantly reduce the risk of liquid leaking for the bins. A small pump would be needed to draw the tea upward through the standpipe.

The units should be watered with the weather conditions in mind. On cloudy, cool days watering of both the units and the plants growing above the units may not be necessary. On hot, sunny days more than one watering per day may be necessary.

Thermometers and moisture meters with long probes are needed to assess temperature and moisture content of the compost when the growing benches are on the units.

CONCLUSIONS

The data for the compost revealed a significant enhancement by the earthworms for nitrate-N and potassium values while no appreciable increase in phosphorus, calcium or magnesium concentrations were observed. The nitrate-N enhancement of the compost will help satisfy the research objective of producing plants with better marketing potential. The enhanced compost could be blended with other organic ingredients to produce a growing medium that would produce the lush-looking starts, bedding and potted plants that consumers demand.

In my opinion, the tea created in this research has the greatest potential from an applied research perspective. The tea data showed good enhancement of nitrate-N, potassium, calcium and magnesium by the earthworms. The data on phosphorus did not indicate a significant difference between the unit with earthworms and the wormless unit. The earthworm enhanced compost tea has potential for direct feeding of plants in a greenhouse environment or possibly in field applications through a drip irrigation system. The tea contains ample available nitrogen that is very difficult to manage in both conventional and organic growing systems. Other than fish emulsion, organic growers do not have a readily available and economically acceptable source of nitrogen that can be applied in a fast acting liquid form. The tea could be applied directly by sidedressing or through fertiligation /trickle irrigation systems. The dilution rate of nitrate-N would need to be

calculated for a known concentration of nitrate-N before it could be applied. But these are topics for further research.
As mentioned earlier in this report, a native earthworm population was inherited with the compost and their population increased significantly with time in Unit B. In the later stages of the research, these earthworms possibly had some bearing on the nutrient testing results. The biological activities of these native earthworms in Unit B more than likely altered the nutrient levels for both the compost and compost tea.

Based on the data collected, the nutrient enhancement of the compost and consequently the compost tea by the earthworms was significant. Nutrient enhanced compost and compost tea hold great promise for farmers who would like to move toward more sustainable methods of growing visually attractive plants.

ACKNOWLEDGEMENTS

The author thanks Dicken Crane owner of Holiday Farm in Dalton, MA for the production of the compost used in this research and for his assistance in selecting an appropriate compost and John Howell, a mainstay at the University of Massachusetts Agricultural Extension Program and now retired for his review and interpretation of the data generated by this research.

OUTREACH

I plan to present the findings from this research at a workshop to be given at the Northeast Organic Farming Association Summer Conference at Hampshire College in August of 2003.