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Investigating Alternative Niche Crop Requirements for Sustainable Production

Final Report

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to

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Executive Summary

Objectives

The objectives of this research were to investigate a select group of native plant species for their requirements in more sustainable production systems, and their use as high-value niche crops for small farms and nurseries. Small farms and nurseries would be the primary beneficiaries of this research in several ways. High-value alternative crops can generate greater profits per acre than that of conventional row crops. Our original hypothesis was that, in contrast to the majority of plant species presently grown by the nursery industry, native species can be grown using methods of fertility and irrigation more sustainable than those outlined in the *Best Management Practices Guide for Producing Container-Grown Plants*. Studies of natural systems have shown many native plants are biologically adapted to compete well in low nutrient, low moisture environments. There is also a general consensus that native plant species can be utilized as low input ornamental plants, needing little fertilizer, water or pesticides after establishment in the landscape. Some varieties of native plant species are already commonly grown by the nursery industry and the species chosen in this research were studied to determine their growth response in container production under various fertilization rates in order to create management recommendations for increased efficiency at the nursery.

It was determined that four species should be investigated for nutrient uptake and post-propagation growth studies. These species included two industry standards, *Clethra alnifolia*, (sweet pepper bush), *Itea virginica* (Virginia sweetspire), a species commonly used for shoreline restoration, *Spartina patens*(salt marsh hay), and a species with great promise as an alternative fruit crop, *Photinia melanocarpa* (black chokeberry or Aronia).

Irrigation research studied new technology in moisture-sensor based irrigation management. A wireless communication and control system from Carnegie Mellon University (CMU) was used to irrigate container-grown plants based on moisture availability in potting soils. Three of the four species studied in the greenhouse were used in these irrigation studies. The moisture sensor system was compared to the present best management irrigation practice of cyclic irrigation, which reduces the irrigation time and increases the frequency of irrigation events.

Results

During both seasons of greenhouse research, it was noted that the nutrient uptake efficiency (fraction of applied nutrient taken up by the plant) was different than expected. In other nutrient studies, nutrient uptake decreased with increasing rates of applied nutrient, while biomass was little affected by high rates compared to medium rates. Interestingly, uptake efficiency was no different or better with increasing rates for all species. Contrary to our hypothesis and other studies, there were dramatic increases of accumulated biomass with the high-rate nutrient treatments and these plants were similarly or more uptake-efficient with the high fertilizer rates. Based on past published plant nutrient studies, it is possible that these native species were more efficient with nutrient use, that is more biomass accumulation per unit of nutrient.

This information does present a contradiction in conventional ideas about plant nutrient fertility and recommendations to nursery managers will reflect these findings. However, along with these recommendations, will be the precautionary messages always taught to nursery managers regarding nutrient management. Since irrigation management is key to nutrient management in the nursery industry, an active irrigation management program is necessary to reduce or prevent nutrient loss through runoff. On an economic note, the use of higher rates of nutrients may reduce the time these plants require for marketability or increase the market value of these plants in shorter time.

In 2007, one of the first sensor-controlled irrigation systems for container production was deployed. In the first year of operation, we successfully calibrated the sensors to the potting substrate and began real-time sensor control, irrigating plants with up to 30 times less water than irrigation scheduled by a clock. In the second year, the system functioned, turning irrigation on and off based on potting soil moisture levels from calibrated set-points, but we discovered Wi-Fi communication and hardware issues that rendered the system no better than cyclic irrigation. That is, while data were collected for 2008 and 2009, high variability in irrigation volumes made comparisons statistically no different.

With a new iteration of hardware, research on this system will continue with a new United States Department of Agriculture, Specialty Crops Research Initiative Grant, giving our research group funding for continued improvements with software, firmware and hardware.

Outreach

An extension program has been initiated that will express the results of this research. This is especially true with Aronia, around which an extension program has been specifically developed. An additional fertility research project with this species has given insight into organic fruit production and yield. To date, over 550 Aronia plants have been distributed to six Maryland farms with the intention of fruit production. Further funding for increased interest and marketing is being sought to develop Aronia as a new Maryland fruit crop.

The information attained from this research will be disseminated through research conferences with an Alternative Crop Extension Program. The end result of this research will add to the integrity of our open spaces by keeping farms in operation by providing information about high-value crop production.

Conclusion

Even though this project is concluded, Maryland will continue to benefit from Agro Ecology's investment of funds for several years to come. Specifically, as part of this project, a new Maryland Alternative Crop Extension Program was initiated. New extension efforts include a website, alternative crop and demonstration tours, research presentations, publications, and grower workshops. Our work with *Photinia melanocarpa* or Aronia, has been particularly promising and several extension programs have already been planned for 2010. Six Maryland farms have adopted this new fruit and further marketing programs and yield research are planned.

Funded research will continue with the sensor controlled irrigation program, with the eventual commercialization of the system by 2014. Increased irrigation efficiency will have a positive effect on the use of water within the Chesapeake Bay watershed. The end result of this study will add to the integrity of our open spaces by keeping farms in operation, providing feasible incomes with sustainable management input.

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Introduction

The objectives of this research are to investigate a select variety of native plant species for their requirements in more sustainable production systems for small farms and nurseries. This research addresses two issues; first, on an economic level, where high-value alternative crops can assist small family farms to maintain solvency; and second, on an environmental level, where research in native plant fertility and water use may aid in greater sustainability for present and potential alternative crop growers.

On a national level, the loss of farmland to urbanization and development is accelerating (about 7.5% loss since 1985), according to the 2007 Natural Resources Inventory (USDA-NRSC, 2009). Incentives for keeping family farms from development are limited and a variety of social and economic factors exist that promote farm loss. The value of farmland continues to increase, especially in areas near urban centers. Real estate values for farmland have been driven by several factors including low interest rates and a demand for nonagricultural land use (USDA-NASS, 2005). In most cases, family investments are tied up in the farm and younger generations show little interest continuing the family business. The economic infrastructure needed to sustain the farm is also disintegrating as markets and supply businesses no longer find profit in maintaining a local presence (The Nature Conservancy, 2002). Together with the increase in land value, selling farmland for development has become a very lucrative retirement plan for farmers.

In Maryland, loss in farmland has occurred since the 1990's. Interestingly, according to the USDA-NASS, (2009) 2007 Census of Agriculture, while there was an 8% decrease in the number of Maryland farms from 1997 to 2002, a 3% increase occurred between 2002 and 2007 as recorded in the 2007 census. However, there has been a steady decrease in farmland of over 6% since 1997. The average size of farms has decreased by 5 acres since 1997. The majority of Maryland farms are 10 to 179 acres in size with an average of 160 acres, and given 2007 census information, one may infer that this farm size may be at greatest risk for development. Even though Maryland grain farmers are paid a premium to support the broiler industry, at per bushel prices of $4 for corn, $5 for wheat, and $9 for soybean, average net profits are much less than $200 per acre. This income is not sustainable for the most common size farms in Maryland.

One alternative to grain production lies within the horticultural industry, the second largest agri-business in Maryland. In Maryland, close to 75% of the nursery operations are family owned and operated (USDA-NASS, 2009) and the average size in the past was approximately 21 acres (Gill, et al., 1994). On acreage of this size, the potential for greater profitability exists with high-value alternative crops, especially those needing low inputs. With nursery and greenhouse sales exceeding grain sales by over 10% in 2002 (USDA-NASS, 2009), alternative crops can at least serve as a supplement to farm income so long as a market exists for the crops.

Both traditional farms and nurseries face similar issues of sustainability. An important issue concerning the switch from row crops to nursery crops is the increase in nutrient application and water use. It has been shown that ornamental nursery crops require nitrogen inputs that exceed typical agronomic rates for corn by a factor of ten or more (Chen, et al., 2001; Dole and Wilkins, 1999) and irrigation demands can exceed one million gallons per acre in one growing season (Ristvey, 2004).

This study intends to address both nutrient and water use by investigating the fertility requirements of several native woody and herbaceous species and to utilize moisture sensing technology in a research nursery setting to improve water use and minimize nutrient runoff. The objectives of this research were to investigate a select variety of native plant species for their requirements in more sustainable production systems. Our original hypothesis was that, in contrast to the majority of plant species presently grown by the nursery industry, native species can be grown using methods of fertility and irrigation more sustainably than those outlined in the *Best Management Practices Guide for Producing Container-Grown Plants* (Yeager et al., 2007). Studies of natural systems have shown many native plants are biologically adapted to compete well in low nutrient, low moisture environments (Chapin, 1983). There is also a general consensus that native plant species can be utilized as low input ornamental plants, needing little fertilizer, water or pesticides after establishment in the landscape (United States Fish and Wildlife Service, no date). Some varieties of native plant species are already commonly grown by the nursery industry and the species chosen in this research were studied to determine their cultural needs including fertilizer and water use. Farmers and nursery managers/owners may find some native plant species as high-value alternatives to traditional agricultural crops, and a commodity that may maintain the sustainability and viability of Maryland agriculture and open space.

Of the plants studied in this research project, one stands out clearly as a certain success. Given the interest in health benefits of certain foods, Aronia, could be a very popular choice for sustainable, low impact agriculture. Gaining popularity in the mid-west, Aronia has many attributes that will make it a viable fruit crop in Maryland. As noted in the following pages, Aronia can be grown in orchards with minimal input. The market value of organic fruits and vegetables, especially if grown locally, attracts premium prices for added value products. If a local interest in fruit production increases, sources of plant stock can be another market for growers in Maryland.

Small farms and nurseries would be the primary beneficiaries of this research in several ways. High-value alternative crops can generate greater profits per acre than that of conventional row crops and will give small farms and nurseries an edge to compete with larger scale nurseries. Additionally, this research may identify markets for these high-value alternative crops that can be grown with cultural practices of greater sustainability. The information gained from this research will be disseminated through an Alternative Crop Extension Program. The end result of this research will add to the integrity of our open spaces by keeping farms in operation by providing information about high-value crop production.

Selected Plants

***Itea virginica* L.** (Virginia Sweetspire)

Itea virginica commonly known as Virginia Sweetspire, is widely distributed throughout the Eastern United States from Pennsylvania south to Florida and as far west as Texas. *Itea virginica's* native habitat is wet and wooded areas and prefers moist acidic soils growing best with partial shade. This species is commonly found in the trade as one of the more popular natives being sold as an alternative to barberry. The variety "Henry's Garnet" carries the dark maroon color in the leaves. A variety of other cultivars are available in the trade. This species was chosen because several retail businesses thought of this species as one of their top selling natives. Additionally, it is a native with few pest species, tolerating a variety of environmental conditions and can be easily propagated through seed (without stratification) and cuttings and can reach saleable age within one growing season (Dirr, 1998) potentially giving these species a short production time in the nursery by fully satisfying growth with irrigation and nutrient needs.

***Clethra alnifolia* L** (Coastal Sweet Pepperbush)

Clethra alnifolia commonly know as Sweet Pepperbush, is another eastern U.S. native species with a range similar to that of *I. virginica*, but extends further north to New Hampshire. *Clethra alnifolia's* habitat is also similar to that of *I. virginica*, competing best in moist woods and wet soils and tolerates a variety of sun light regimes. It is commonly found in the trade both as cultivars and as the straight species. As with *I virginica*, *C. alnifolia* has few pests. The flower fragrance makes this plant a sought-after landscape species and so it is a popular native plant sold at most retail centers. Propagation through seed requires stratifying, unlike *I. virginica*, but cuttings are relatively easy to grow. *Clethra alnifolia* should also have a quick production time in the nursery given appropriate cultural practices as those seen in nurseries.

Spartina patens Aiton (Muhl.) (Salt Marsh Hay**)**

Spartina patens, commonly known as salt-marsh hay or saltmeadow cordgrass are found extensively throughout the salt marsh habitat along the Atlantic Coast. In the picture to the right, two species commonly found along the Atlantic Coast are *S. alternaflora* along the shoreline and *S. patens* above the mean-high tide line. Both species are presently being grown for vegetative shoreline restoration projects. These plants can be sold at a price ranging between $0.40 and $1.00 a plug and may be a valuable niche crop for supplemental income.

Photinia melanocarpa Michx., K.R.Roberstson and Phipps (Black Chokeberry or Aronia)

Photinia melanocarpa or Aronia is native from New Foundland and Northern Quebec south, throughout the Midwest and Southeast piedmont into eastern Texas but rarely on coastal plains. While being an eastern North American native species, it has a long history of fruit production in Eastern Europe. By far this is the most promising crop studied in this research for a variety of reasons. Aronia is marketable on several levels including but not limited to an ornamental, a restoration/mitigation species, and as a fruit crop. Several products can be made from the berries including juice, extracts, jelly, wine and other food products. The berries have a soluble solid content of up to 21% (brix) and are known to contain high concentrations of antioxidents (anthocyanins). A recent study by Indiana University School of Medicine researchers found that chokeberry extract appears to possess potentially strong beneficial properties with regards to the function of coronary arteries in health and disease (Bell and Gochenaur, 2006). Other studies suggest medical uses for diabetes, urinary tract infections and gastrointestinal health (Sabine and Rawel, 2008). Aronia is presently the market name for this plant.

This species seems to be tolerant of environmental stressors, and has great resistance to most pests and diseases. This species is easily propagated by seeds (stratified) or cuttings. Additional research on organic production of this species is being conducted at the University of Maryland's Wye Research and Education Center. This research is also presented in this report.

Viburnum prunifolium **L.** (Blackhaw Viburnum)

Viburnum prunifolium is native to eastern U.S from Texas north to Wisconsin and east to New York. It was chosen for its ornamental value along with its potential as a mitigation and restoration species. *Viburnum prunifolium* was chosen for its popularity and high value in specialty retail businesses. It has few if any pest species that adversely affect health and growth and is very tolerant of a variety of environmental conditions. Propagation may prove to be difficult as cuttings go into dormancy after rooting and seeds require several dormancy cycles before germination. A cold period may be needed after cuttings root, extending turnaround time in the nursery over one year. Due to its difficult cultural needs and the fact that the plants went dormant in the middle of the summer 2008 during irrigation trials, it was removed from the irrigation study in 2009. For the same reason, this species was not utilized in the greenhouse fertility trials.

Greenhouse Container Fertility Studies

Two seasons of greenhouse research were conducted to determine optimal fertility requirements to minimize fertilizer use and increase nutrient efficiency without sacrificing growth. Four of the five species described above were studied excepting *V. prunifolium*. The second year of research focused again on these species in order to answer questions of fertility rates brought about from the first study season.

2007 Greenhouse Fertility Studies Methods

One year-old seedlings of each species were transplanted into #2 trade containers with an 80% pine bark and 20% sphagnum peat potting medium. Lab analysis of available N and P in the potting medium was analyzed to be less than 20 mg N and 5 mg P in each container at study initiation. One plant was considered an experimental unit. Due to a shortage of one-year old *P. melanocarpa* seedlings, 18 month old seedlings were included in the experiment.

Prior to study initiation, a baseline harvest was performed on 5 plants from each species at the end of February 2007. Harvesting is a destructive sampling process in which the plant is removed from its container, and separated into leaf, stem and washed root tissues. Three more harvests starting in May were performed on *C. alnifolia, I. virginica*, and *S. patens.* The plant tissues were then dried in an oven at 60 ^{o}C for 48 hours, weighed, and milled through a 100 μm screen. Finally, tissue samples were analyzed for N and P concentrations and then normalized for nutrient content using dry weights.

The study duration was 20 weeks for *C. alnifolia, I. virginica*, and *S. patens* and 34 weeks for *P. melanocarpa* starting the first week of March 2007. Three more harvests for each species were performed in May, June and July at 14, 17 and 20 weeks all species. The study was carried further into the growing season with *P. melanocarpa*, with harvests at 26 weeks and 34 weeks, ending in October 2007.

The experimental design was completely randomized with each species placed on separate benches. Treatment applications of three fertility rates were applied to plants selected randomly at the beginning of the study. Two of three treatments consisted of applications of soluble fertilizer applied as a substrate drench of 250 ml aliquots, once per week. The nutrient solution was made with a custom blend, soluble 0:4.4:34 P:K fertilizer with a full compliment of micronutrients. Ammonium nitrate was added as a N source. The high rate consisted of this solution which delivered 150 mg nitrogen (N) and 15 mg phosphorus (P) per week in 250 mls. The low rate was half the high rate or 75 mg N and 7.5 mg P made by diluting the high rate. The nutrient solution was poured onto the potting medium of each plant once per week. During the 20 week study period, *C. alnifolia, I. virginica*, and *S. patens* received a total of 3.0g N (high rate) and 1.5 g N (low rate). During the longer 30 week study period for *P. melanocarpa*, the plants received a total of 5.1 g N (high rate) and 2.6 g N, (low rate).

The third treatment was a spray application of a low-biuret foliar urea solution. Foliar urea is a common method for applying N to citrus (Lea-Cox and Syvertsen, 1995) and is effective for supplemental N fertility in peach (Johnson and Amdris, 2001). The urea contained 46% N and less than 0.25% biuret. The foliar spray solution contained a 1% concentration of urea which was the maximum that could be applied as a higher concentration proved detrimental to leaves on test plants prior to study initiation. The volume of spray administered was based on relative leaf area, as follows: *Clethra alnifolia* plants received 3 doses of 0.9 mL twice weekly for a total of 0.25 g N. *Itea virginica* and *S. patens* received 2 doses of the same volume twice weekly for a total of 0.17 g N. *Photinia melanocarpa* received 2 doses of the same volume twice weekly for a total of 0.28 g N during the 34 week study period. However, since the total amount of urea spray actually coming into contact with the leaves of each plant was not measured, nutrient efficiencies were not calculated for this treatment. In addition to the foliar urea spray, a nutrient solution consisting of the same soluble fertilizer used in the high treatment , without N, was applied onto the substrate surface of each plant once per week. Each species had five replicates per treatment at each harvest.

Irrigation (spray stakes) was carefully adjusted throughout the study so that plant needs were met while keeping leachate to 15% or less. Leachate volume was monitored by placing a drip tray below randomly selected containers. It is likely that at least 15% of the N and P were leached from the container, so nutrient uptake efficiency and use efficiency calculations were based on 85% N and P availability.

Dry weights and nutrient uptake for each species at each harvest were statistically analyzed using ANOVA (SAS Institute Inc., Cary, NC) and all graphics have statistical standard error bars.

2007 Greenhouse Fertility Studies Results and Discussion

Itea virginica

The dry mass comparison of *I. virginica* (Figure 1 and Table 1) shows that this species responded with greater dry mass with the higher N rate than the low N rate or urea treatment. At first, there were no differences in growth between the rates until the start of May 2007. Figure 2 A, B, and C shows the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. Most of the dry mass is being allocated towards leaf tissue in the highest N treatment. Interestingly, root growth in *I. virginica* was not different between 150 and 75 mg N per week treatments. Root growth can be inhibited with high nutrient rates in plants so this does not follow present understanding about the effects of nutrient rate on root growth (Ristvey et al., 2007). Urea was not an effective N source and proved limiting for this species.

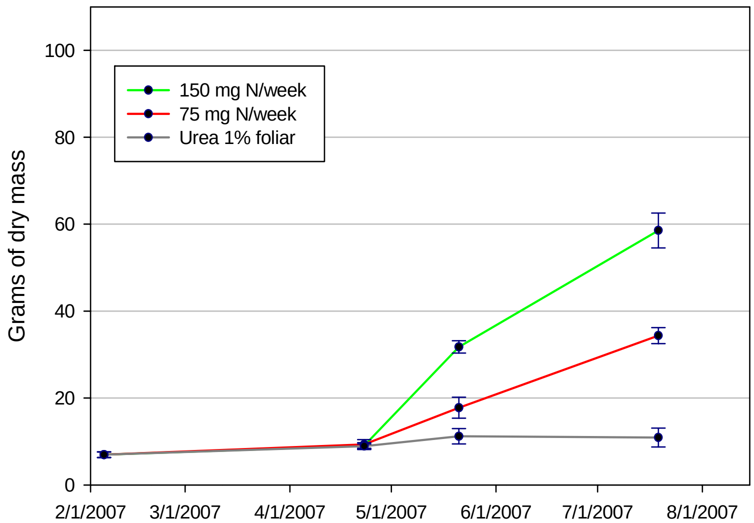

Figure 1. Comparison of average dry mass accumulation in Itea between three nitrogen treatments, 150 mg, 75 mg per week, and 1% urea applied twice weekly as a foliar spray. Error bars represent 1 SE.

Table 1. Average total dry mass of *I. virginica* under two fertility rates and foliar urea during a Spring/Summer 2007 Fertility Trial.

	I. virginica		
2007	150 N	75 N	Urea[x]
Total DM (g)	**58.6** ± 4.00	**34.4** ± 1.85	**10.9** ± 2.18

Along with the increase in dry mass, both N and P uptake was slow until after the May harvest (Figures 3 and 4). Nutrient uptake efficiency for *I. virginica* in the 2007 study (Table 2) was higher in the high nutrient treatment than the low or urea treatment and during the course of the study, nutrient uptake efficiency increased as plants increased biomass, probably due to increased root growth.

Nutrient partitioning graphs for N (Figure 5 A,B and C) and P (Figure 6 A,B and C) indicate that the leaves were a sink for N and stems were a sink for P in plants under the high fertility treatment. The low and urea treatment show how N and P are utilized under deficient conditions.

Table 2. Average nitrogen uptake efficiency (**NUpE**), phosphorus uptake efficiency (**PUpE**) of *I. virginica* under two fertility rates and foliar urea and a 15% target leaching fraction during a Spring/Summer 2007 Fertility Trial.

	I. virginica		
2007	150 N	75 N	Urea
NUpE (%)	**18.4** ± 2.02	**10.9** ± 1.09	---
PUpE (%)	**30.2** ± 1.78	**27.7** ± 1.78	**3.62** ± 1.41

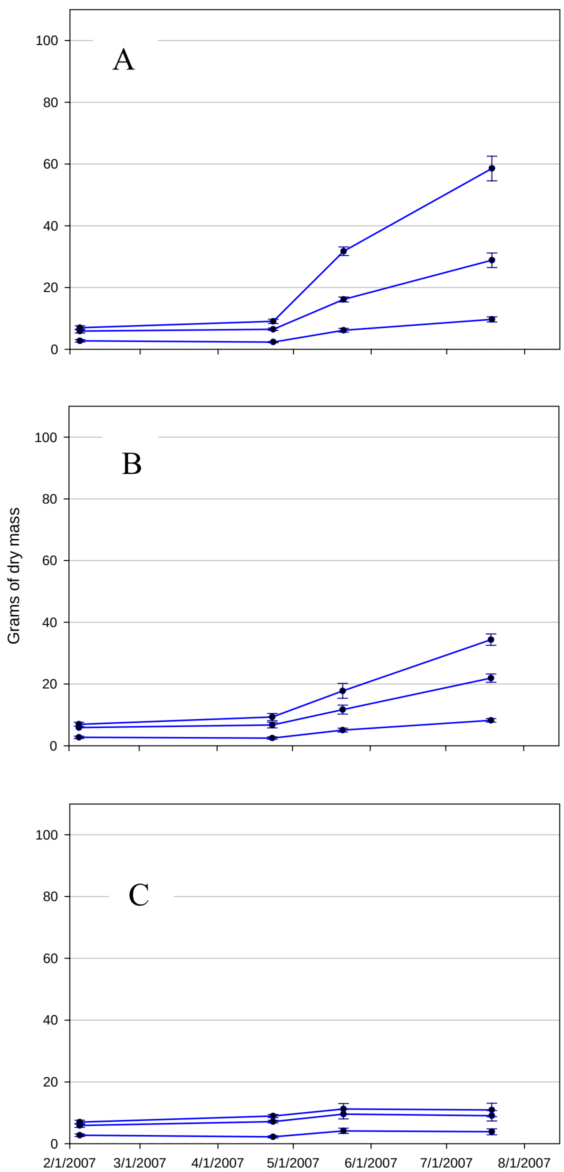

Figure 2 A, B and C. Dry mass tissue partitioning graphs of *I. virginica* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly. The top line represents total dry mass. The area under each line from top to bottom represents leaf, stem and root dry mass. Error bars are 1 SE.

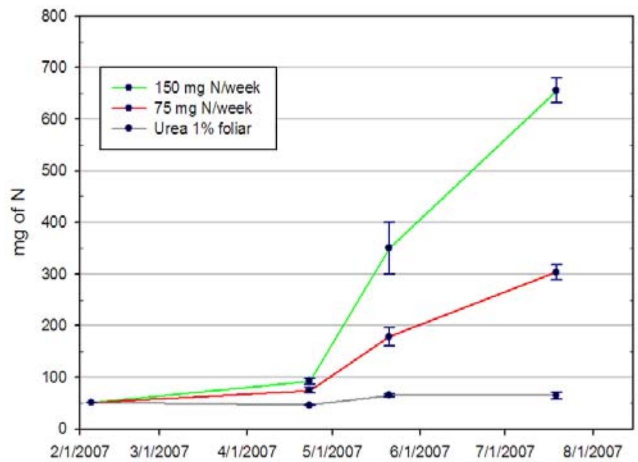

Figure 3. Comparison of average N accumulation in *I. virginica* between three nitrogen treatments, 150 mg per week 75 mg per week, and 1% urea applied twice weekly as a foliar spray over a period of 20 weeks. Error bars represent 1 SE.

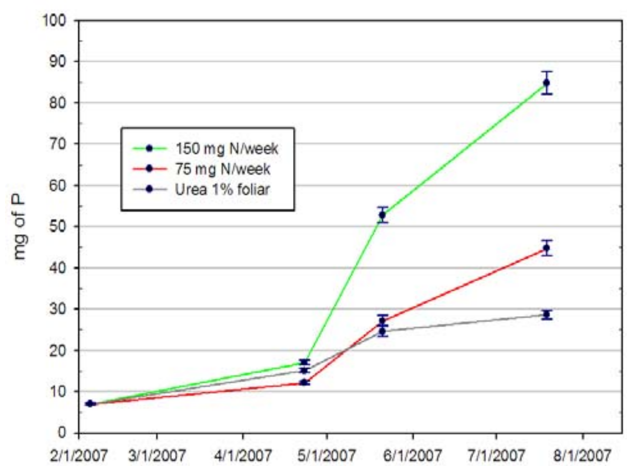

Figure 4. Comparison of average P accumulation in *I. virginica* between three nitrogen treatments, 15 mg P per week, 7.5 mg per week, and 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 20 weeks. Error bars represent 1 SE.

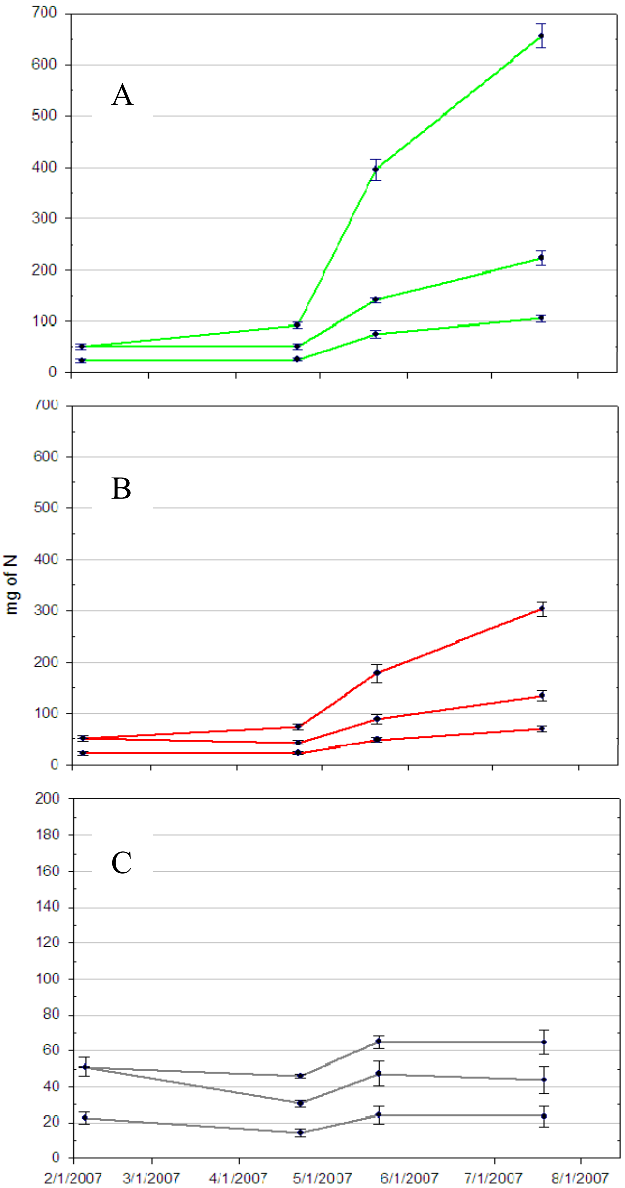

Figure 5 A, B and C. Average tissue N partitioning graphs of *I. virginica* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly over a period of 20 weeks. The top line represents total N content. The area under each line from top to bottom represents leaf, stem and root N content. Error bars are 1 SE.

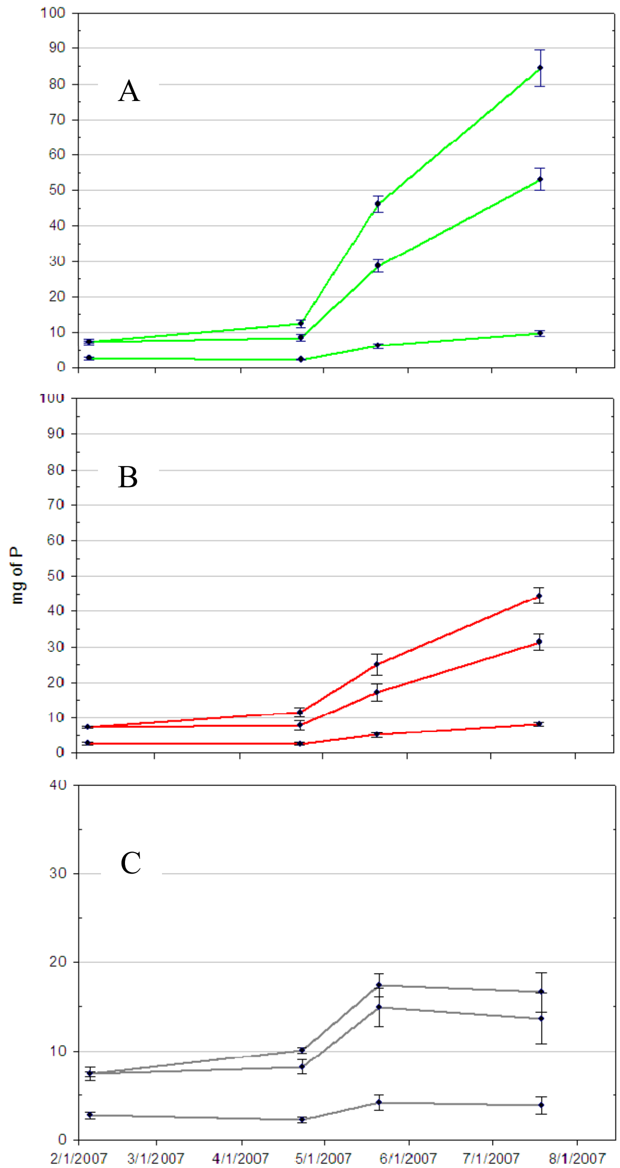

Figure 6 A, B and C. Average tissue P partitioning graphs of *I. virginica* given A) 15 mg P per week, B) 7.5 mg P per week, and C) 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 20 weeks. The top line represents total P content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

Clethra alnifolia

Dry mass for *C. alnifolia* (Table 3) and treatment comparisons (Figure 7) show that, similar to *I. virginica*, this species responded significantly better to the higher N rate than the median or foliar urea. Like in *I. virginica*, there were little differences in growth between the rates until the start of May 2007. Figure 8 A, B, and C shows the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. Most of the dry mass is being allocated towards leaf tissue in the highest N treatment and the highest N treatment had greater growth in all tissues. Contrary to present understanding about root/nutrient interactions, root growth in *C. alnifolia* was significantly greater with the highest N rate in this study. Urea was not effective as a N source and proved limiting for this species.

Table 3. Average total dry mass and root dry mass of *C. alnifolia* under two fertility rates and foliar urea during a Spring/Summer 2007 Fertility Trial.

	C. alnifolia		
2007	150 N	75 N	Urea[x]
Total DM (g)	**78.1** ± 4.59	**42.6** ± 1.66	**28.3** ± 2.50

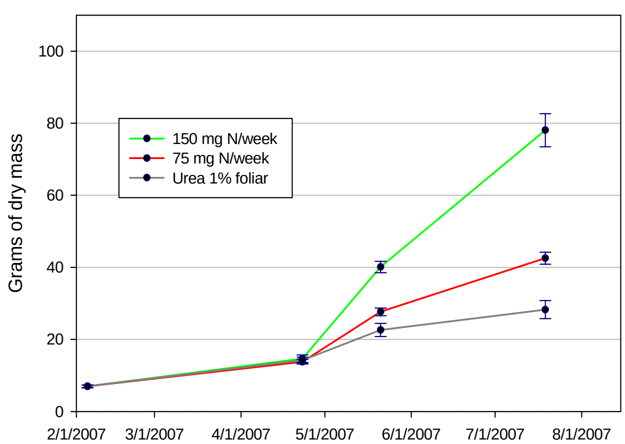

Figure 7. Comparison of average dry mass accumulation in *C. alnifolia* between three nitrogen treatments, 150 mg, 75 mg per week, and 1% urea applied twice weekly as a foliar spray. Error bars represent 1 SE.

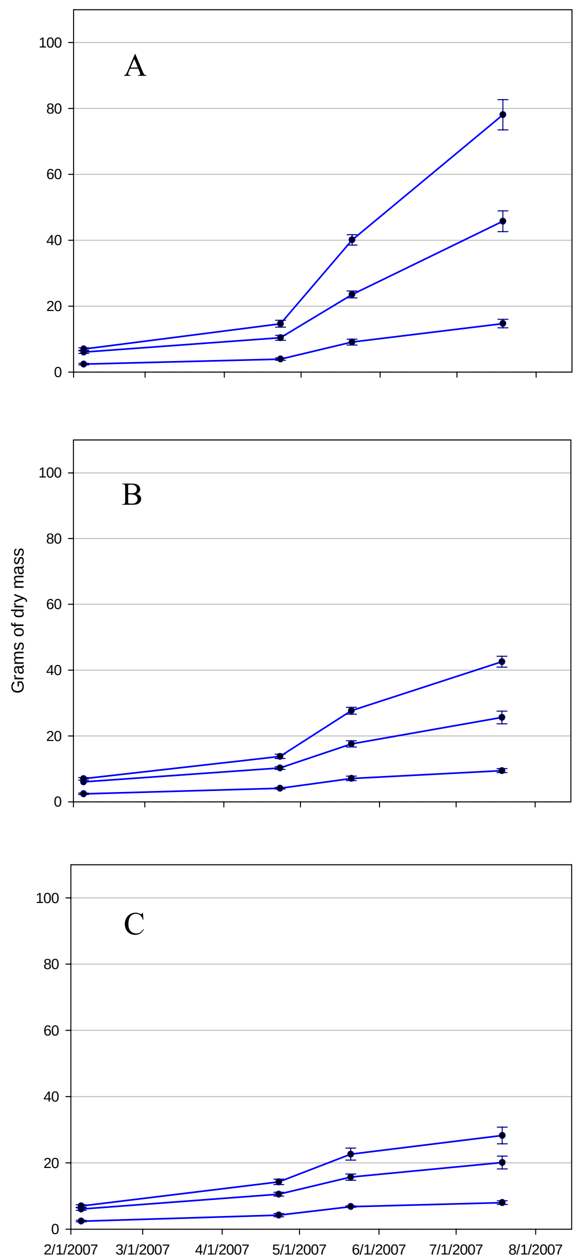

Figure 8 A, B and C. Dry mass tissue partitioning graphs of *C. alnifolia* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly. The top line represents total dry mass. The area under each line from top to bottom represents leaf, stem and root dry mass. Error bars are 1 SE.

As with *I. virginica*, dry mass and both N and P uptake were slow until after the May harvest (Figures 9 and 10). Nutrient uptake efficiency in *C. alnifolia* in the 2007 study (Table 4) was significantly higher in the high nutrient treatment than the low or urea treatment and that like *I. virginica*, during the course of the study, nutrient uptake efficiency increased as plants increased biomass, probably due to increased root growth. The most dramatic growth was between the May and June harvest where *C. alnifolia* appears to have the greatest growth rate.

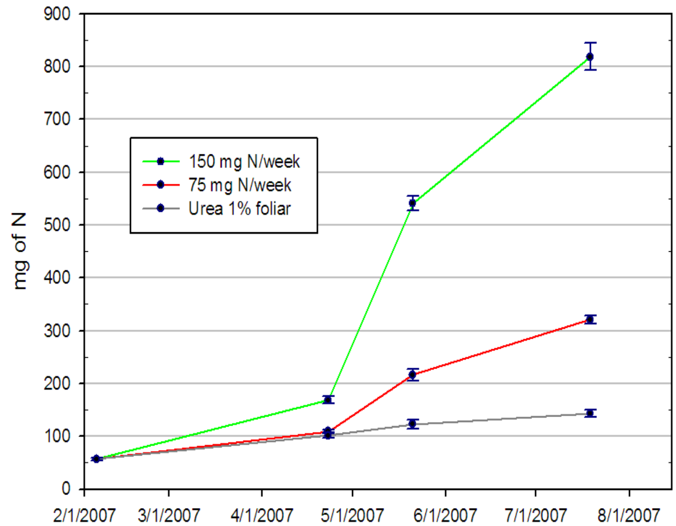

Figure 9. Comparison of average N accumulation in *C. alnifolia* between three nitrogen treatments, 150 mg per week, 75 mg per week, and 1% urea applied twice weekly as a foliar spray over a period of 20 weeks. Error bars represent 1 SE.

Table 4. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *C. alnifolia* under two fertility rates and foliar urea and a 15% target leaching fraction during a Spring/Summer 2007 Fertility Trial.

	C. alnifolia		
2007	150 N	75 N	Urea[x]
NUpE (%)	**29.9** ± 1.05	**19.8** ± 1.05	---
PUpE (%)	**30.5** ± 1.17	**28.2** ± 2.58	**8.49** ± 0.46

Nitrogen and P partitioning are shown in Figure 11 A, B and C and Figure 12 A, B and C, respectively. As with *I. virginica*, the leaves were a sink for N and stems were a sink for P in plants under the high fertility treatment. The low and urea treatment show how N and P were utilized under deficient conditions. Leaves continue to have most N but P is distributed more evenly throughout the plant tissues.

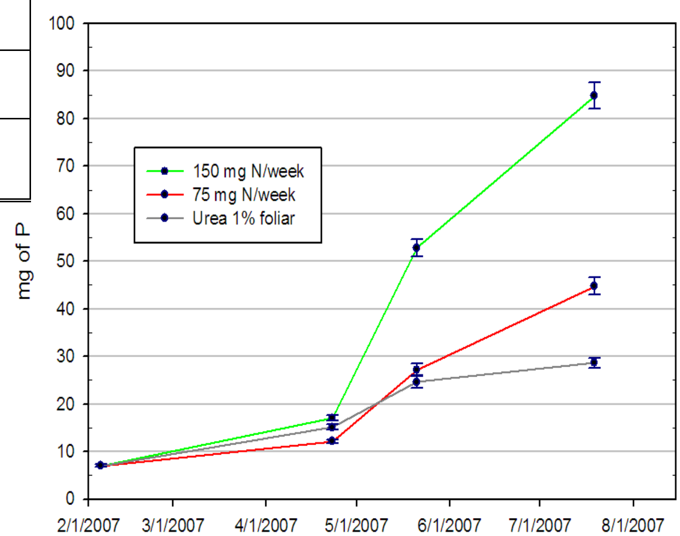

Figure 10. Comparison of average P accumulation in *C. alnifolia* between three nitrogen treatments, 15 mg P per week, 7.5 mg per week, and 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 20 weeks. Error bars represent 1 SE.

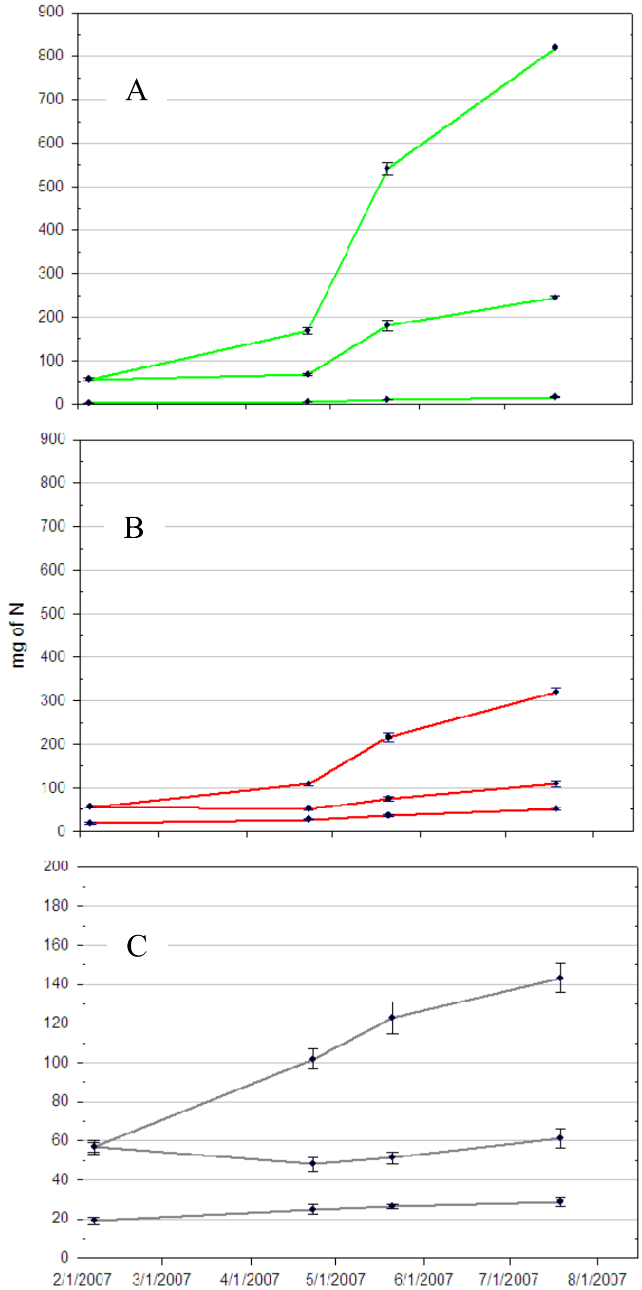

Figure 11 A, B and C. Average tissue N partitioning graphs of *C. alnifolia* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly over a period of 20 weeks. The top line represents total N content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

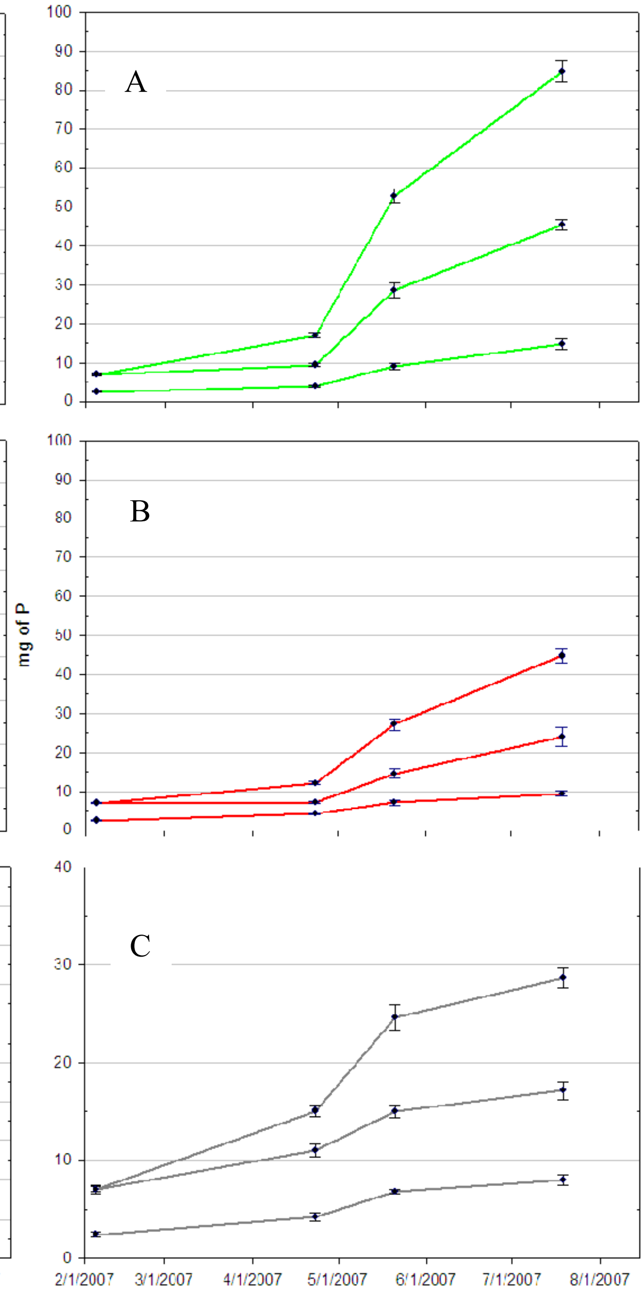

Figure 12 A, B and C. Average tissue P partitioning graphs of *C. alnifolia* given A) 15 mg P per week, B) 7.5 mg P per week, and C) 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 20 weeks. The top line represents total P content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

Spartina patens

The dry mass treatment comparison of *S. patens* (Table 5 and Figure 13) shows this species also responded with greater dry mass to the higher N rate than the median N rate or foliar urea. As in the other species, there were little differences in growth between the rates until the start of May 2007. Figure 14 A, B, and C shows the dry mass partitioning of shoots (leaves and culms) and roots as areas under the lines, the top line representing total dry mass. As with *I. virginica*, most of the dry mass is being allocated towards leaf tissue in the highest N treatment and the highest N treatment had greater growth in all tissues. Similar to *C. alnifolia*, root growth responded with greater dry mass with the higher N rates. Spartina did not respond well to urea as very little dry mass was accumulated thoughout the study.

Table 5. Average total dry mass and root dry mass of *S. patens* under two fertility rates and foliar urea during a Spring/Summer 2007 Fertility Trial.

	S. patens		
2007	150 N	75 N	Urea[x]
Total DM (g)	**64.5** ± 7.38	**22.8** ± 3.33	**4.1** ± 0.48

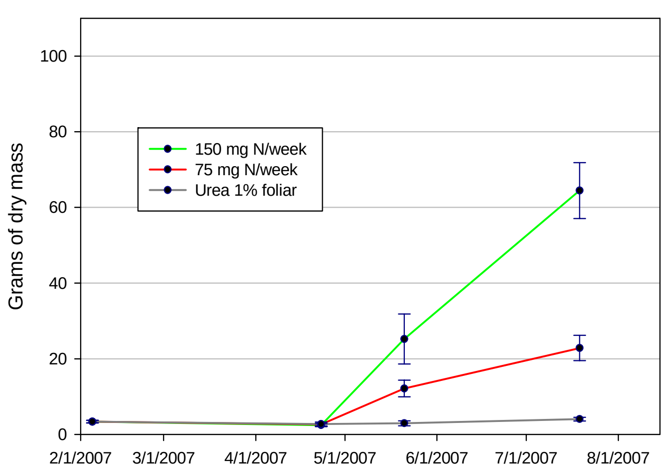

Figure 13. Comparison of average dry mass accumulation in *S. patens* between three nitrogen treatments, 150 mg, 75 mg per week, and 1% urea applied twice weekly as a foliar spray. Error bars represent 1 SE.

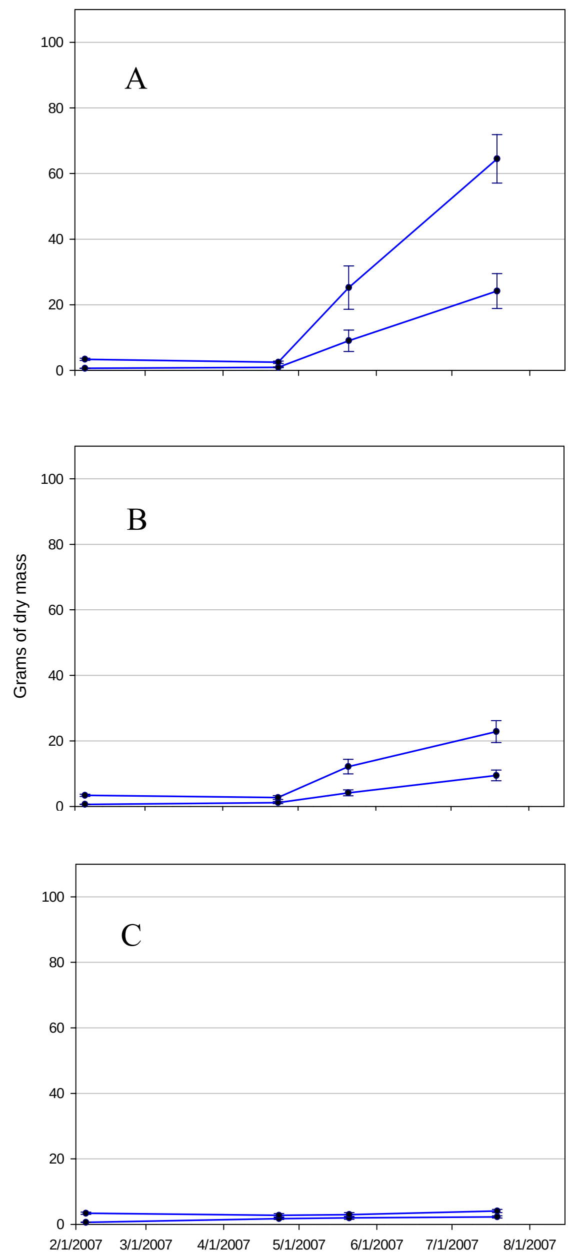

Figure 14 A, B and C. Dry mass tissue partitioning graphs of *S. patens* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly. The top line represents total dry mass. The area under each line from top to bottom represents shoot and root dry mass. Error bars are 1 SE.

Nitrogen uptake efficiency was higher (Table 6) with the high nutrient rate compared to the low rate, but no difference was found with P uptake efficiency. Again *S. patens* is another species that does not follow conventional ideas about nutrient uptake efficiency and application rate. Nutrient uptake in *S. patens* for N (Figure 15) and P (Figure 16) was similar to *C. alnifolia* where between May and June, the greatest nutrient uptake rate occurred. Unlike *C. alnifolia*, this was not reflected in biomass accumulation, where in *S. patens*, growth rate was almost linear (Figure 13). At some point, *S. patens* given the high nutrient rate of 150 mg N per week, slowed nutrient accumulation after June, but continued a steady increase in biomass. It is important to recognize the high variability with this harvest was due to a low dry mass data point.

Table 6. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *S. patens* under two fertility rates and foliar urea and a 15% target leaching fraction during a Spring/Summer 2007 Fertility Trial.

2007	*S. patens* 150 N	75 N	Urea[x]
NUpE (%)	**29.9** ± 1.05	**19.8** ± 1.05	---
PUpE (%)	**30.5** ± 1.17	**28.2** ± 2.58	**8.49** ± 0.46

Nitrogen and P partitioning are shown in Figure 17 A, B and C and Figure 18 A, B and C, respectively. In *S. patens*, shoot tissue contains greater N content than root tissue in the high N treatment, but P is relatively evenly distributed between shoots and roots.

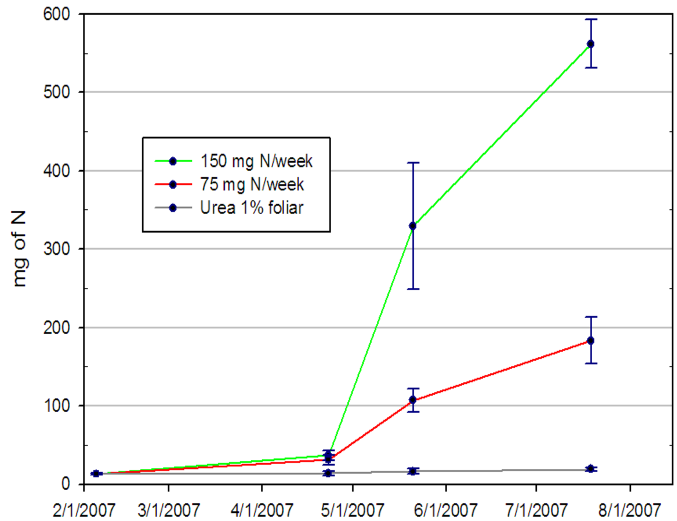

Figure 15. Comparison of average N accumulation in *S. patens* between three nitrogen treatments, 150 mg per week, 75 mg per week, and 1% urea applied twice weekly as a foliar spray over a period of 20 weeks. Error bars represent 1 SE.

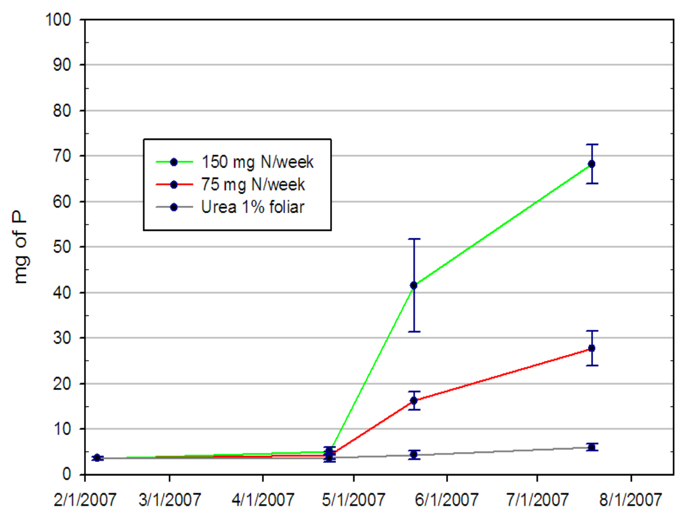

Figure 16. Comparison of average P accumulation in *S. patens* between three nitrogen treatments, 15 mg P per week, 7.5 mg per week, and 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 20 weeks. Error bars represent 1 SE.

In the low N and urea treatments, both N and P are evenly distributed. This shows how the plant allocates N and P to maintain physiological functions, but clearly these rates are limiting growth in *S. patens*.

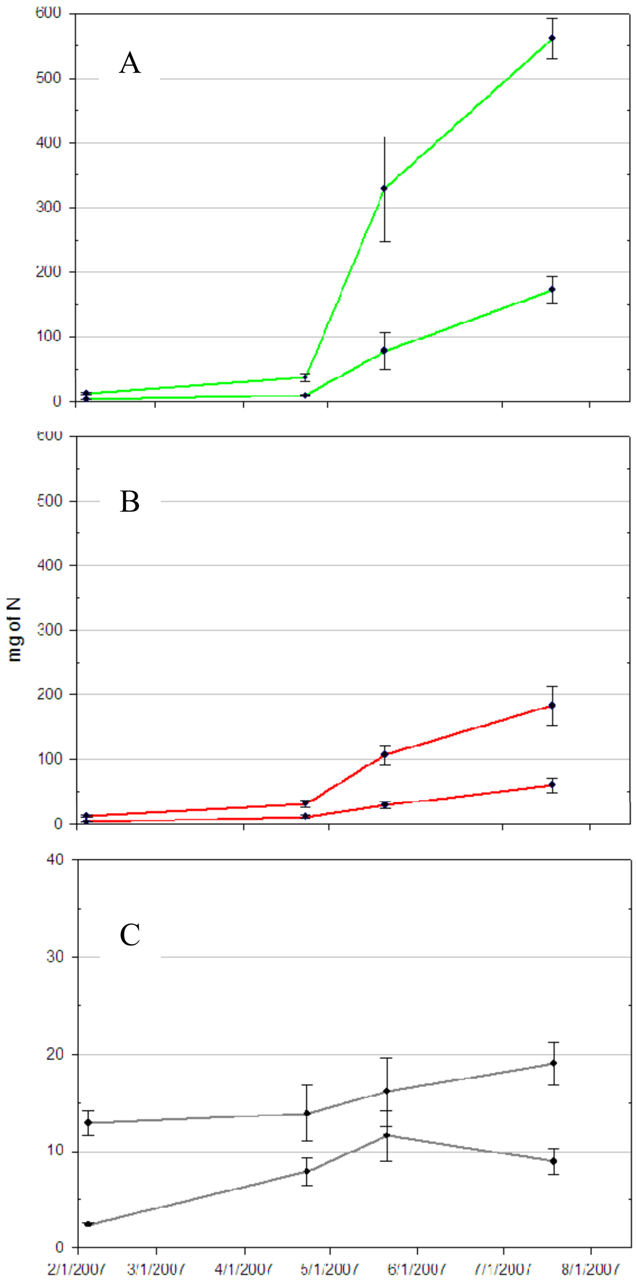

Figure 17 A, B and C. Average tissue N partitioning graphs of *S. patens* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly over a period of 21 weeks. The top line represents total N content. The area under each line from top to bottom represents shoot and root P content. Error bars are 1 SE.

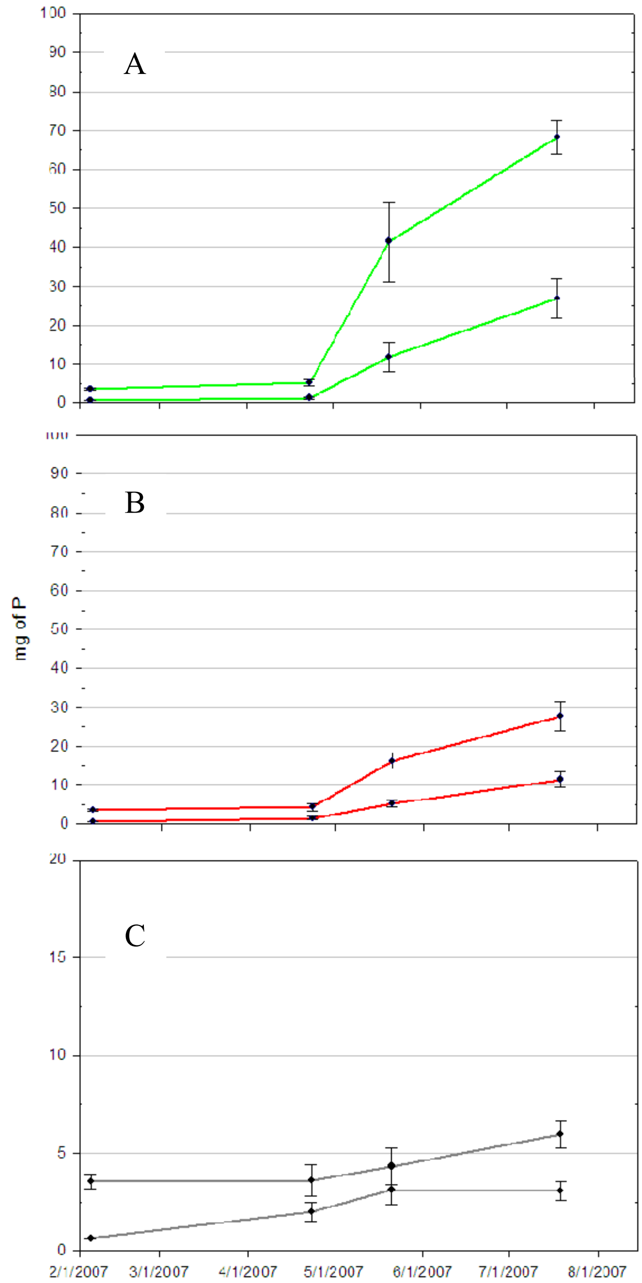

Figure 18 A, B and C. Average tissue P partitioning graphs of *S. patens* given A) 15 mg P per week, B) 7.5 mg P per week, and C) 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 21 weeks. The top line represents total P content. The area under each line from top to bottom represents shoot and root P content. Error bars are 1 SE.

Photinia melanocarpa

Photinia melanocarpa was taken through a full growing season (34 weeks). This species responded with greater dry mass to the higher N rate than the median N rate or foliar urea (Table 7). The dry mass treatment comparison of *P. melanocarpa* (Figure 19) shows the same pattern as the other three study species, as there were little differences in growth between the rates until the start of May 2007. Figure 20 A, B, and C shows the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. The highest N treatment had greater growth in all tissues, and interestingly, in the highest N treatment *P. melanocarpa* allocated a proportionally greater amount dry mass into root tissue than the other species.

Table 7. Average total dry mass and root dry mass of *P. melanocarpa* under two fertility rates and foliar urea during a Spring/Summer 2007 Fertility Trial.

	P. melanocarpa		
2007	150 N	75 N	Urea
Total DM (g)	**98.1** ± 8.01	**40.5** ± 2.59	**5.0** ± 0.61

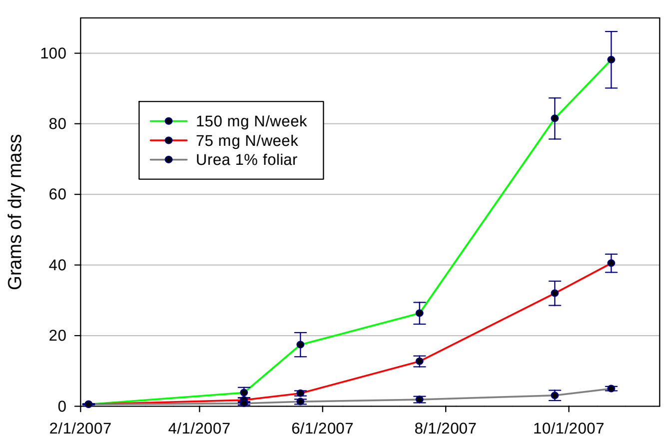

Figure 19. Comparison of average dry mass accumulation in *P. melanocarpa* between three nitrogen treatments, 150 mg, 75 mg per week, and 1% urea applied twice weekly as a foliar spray. Error bars represent 1 SE.

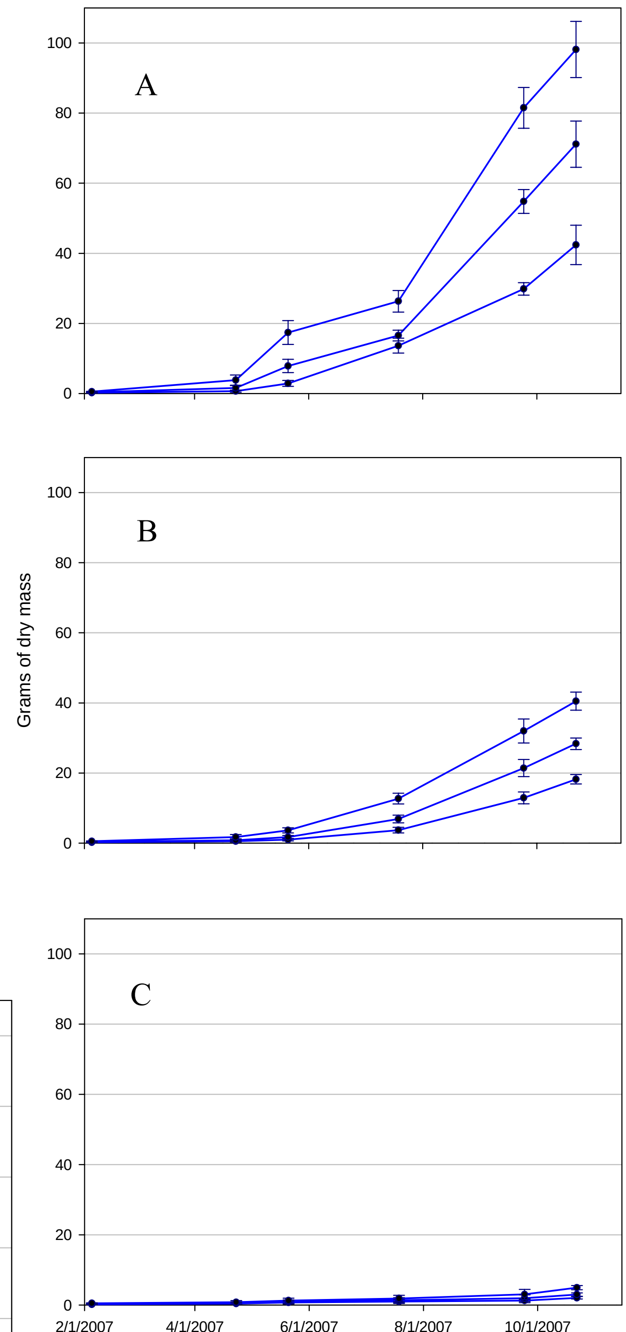

Figure 20 A, B and C. Dry mass tissue partitioning graphs of *P. melanocarpa* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly. The top line represents total dry mass. The area under each line from top to bottom represents leaf, shoot and root dry mass. Error bars are 1 SE.

Table 8 compares average N uptake efficiency between the rates. Greater N uptake efficiency occurred with the high N rate than with the low N rate and greater N content can be seen with the high N rate in Figure 21 due to greater biomass and luxurious consumption of N. There was no difference in P uptake efficiency between high and low treatment and foliar urea could not promote enough growth for significant P uptake as seen in the other N treatments. Figure 22 shows average P uptake between treatments increasing with rate, as more biomass was accumulated and more P is assimilated.

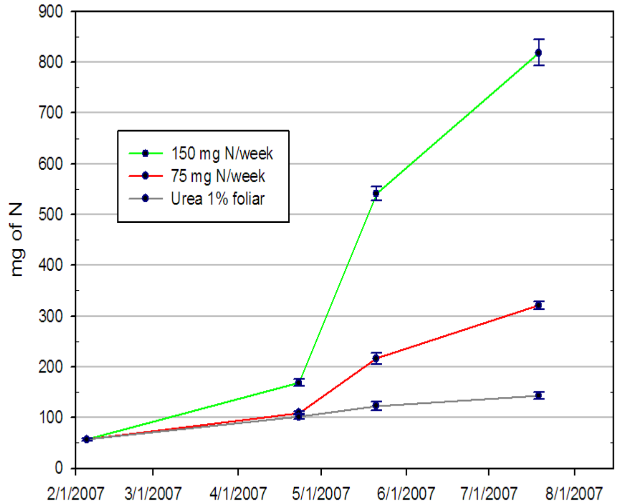

Figure 21. Comparison of average N accumulation in *P. melanocarpa* between three nitrogen treatments, 150 mg per week, 75 mg per week, and 1% urea applied twice weekly as a foliar spray over a period of 34 weeks. Error bars represent 1 SE.

Table 8. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *P. melanocarpa* under two fertility rates and foliar urea and a 15% target leaching fraction during a Spring/Summer 2007 Fertility Trial.

	P. melanocarpa		
2007	150 N	75 N	Urea[x]
NUpE (%)	**34.5** ± 3.45	**26.1** ± 1.95	---
PUpE (%)	**36.2** ± 3.76	**36.0** ± 2.73	**5.7** ± 0.93

Figures 23 A,B and C and 24 A, B and C show N and P distribution respectively in *P. melanocarpa*. Different from other plants, *P. melanocarpa* tissues seem to have distributed the N and P in the high fertility rate towards roots and less of stems and leaves, contrary to the other species studied. While N and P content is different with the different rates, nutrient content in the different tissues shows similar allocation as in the high nutrient rate.

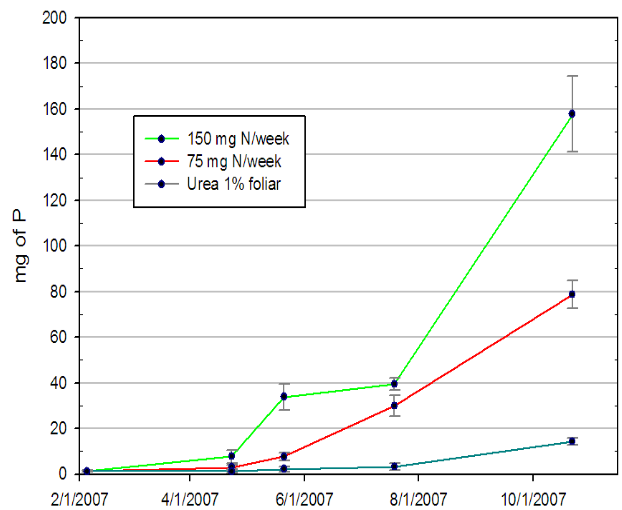

Figure 22. Comparison of average P accumulation in *P. melanocarpa* between three nitrogen treatments, 15 mg P per week, 7.5 mg per week, and 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 34 weeks. Error bars represent 1 SE.

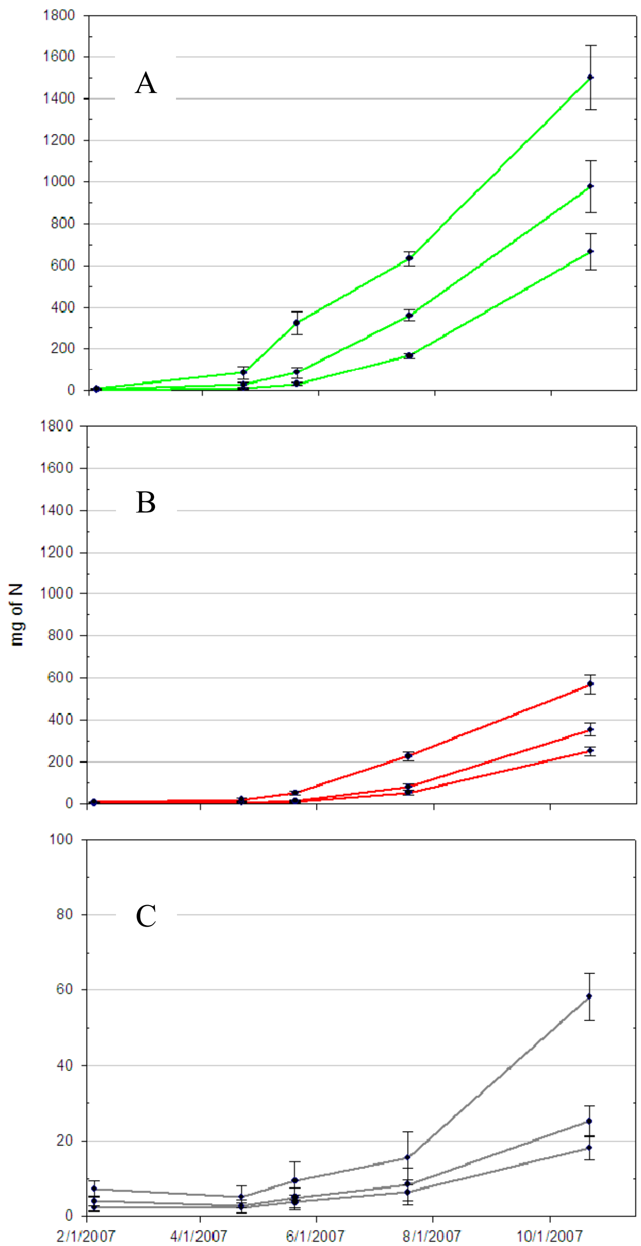

Figure 23 A, B and C. Average tissue N partitioning graphs of *P. melanocarpa* given A) 150 mg N per week, B) 75 mg N per week, and C) foliar application of 1% urea twice weekly over a period of 34 weeks. The top line represents total N content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

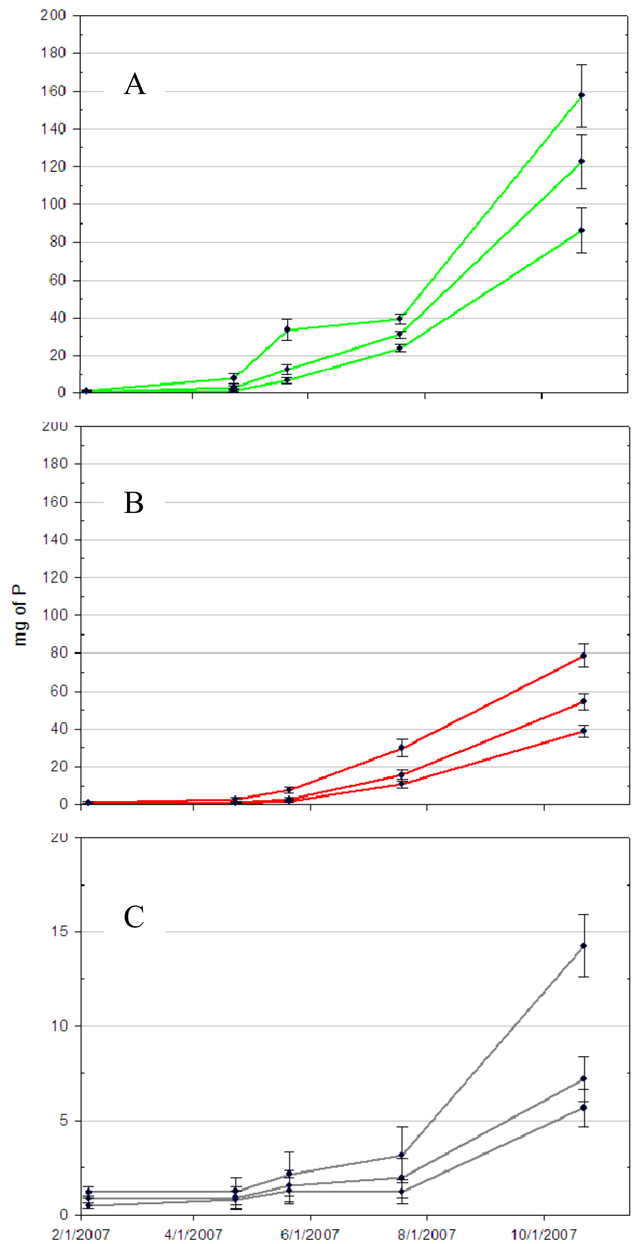

Figure 24 A, B and C. Average tissue P partitioning graphs of *P. melanocarpa* given A) 15 mg P per week, B) 7.5 mg P per week, and C) 7.5 mg P per week with foliar application of 1% urea twice weekly over a period of 34 weeks. The top line represents total P content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

The nutrient rates utilized in the 2007 study showed that each of the species tested responded best to the high nutrient rate and, for the most part, were either as efficient or more efficient in taking up the high nutrient rate applied compared to the low rate. Our hypothesis was that the low N rate would produce plants as large as plants given a high rate of N with better efficiencies based on Ristvey et al. (2007). A foliar urea application was examined as an alternative method for fertilization but this did not prove to be an effective method for applying N as seen in the growth responses of all plants. Contrary to our expectations, plants receiving the high N rate of 150 mg N per week were significantly larger and exhibited nutrient uptake efficiencies similar to or greater than plants receiving the low N treatment of 75 mg N per week.

2008 Greenhouse Fertility Study Methods

Since the high and low nutrient treatment rates were applied once per week as a soluble feed in the 2007 study, another study was developed for the 2008 growing season to further define nutrient rates that would be more effective for increasing growth, growth rate and nutrient uptake efficiency. Since the low rate seemed limiting for growth, we chose higher rates in the 2008 greenhouse study, and the same four species were used again for comparison. The same study methods were employed as utilized in the 2007 study except for dropping the foliar urea treatment and changing the fertilizer rates. The study began in March 2008 and was terminated in July with three species, *I. virginica, C. alnifolia* and *S. patens* but continued into October with *P. melanocarpa*.

In addition to increasing the fertility rates, two of the three fertility treatments were administered as split applications twice a week, three days apart. A rate of 150 mg N per week was compared to two split rates of either 225 mg N, in two 112.5 mg N applications per week and 150 mg N per week in two 75 mg N applications per week. Phosphorus was once again applied at 10% of the N rate for each treatment. Since the 2007 study determined that the plants responded best to the higher nutrient rate of 150 mg N per week our hypothesis was that plants would respond with greater growth with high rates and higher efficiencies with split applications.

2008 Greenhouse Fertility Studies Results and Discussion

Itea virginica

The dry mass treatment comparison of *I. virginica* (Figure 25 and Table 9) shows that this species responded with greater dry mass to the split application of 225 mg per week than either the single or split 150 mg N application. Figure 26 A, B, and C shows the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. Most of the dry mass is being allocated equally towards stem tissue in all treatments. Root growth in *I. virginica* was no different between the N rates. Plants responded to the 225 mg/week N application by greater leaf growth, however, *I. virginica* showed no greater growth response towards either split or single 150 mg per week.

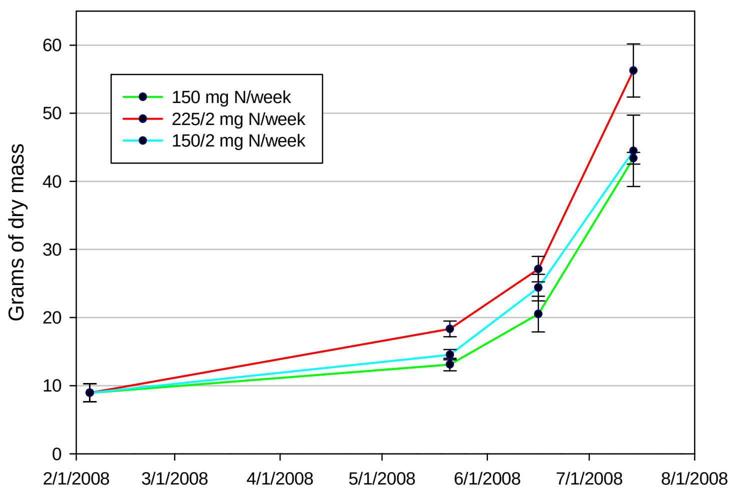

Figure 25. Comparison of average dry mass accumulation in *I. virginica* between a weekly nitrogen application of 150 mg, and two split nitrogen applications of 225 mg per week and 150 mg per weeks. Error bars represent 1 SE.

Table 9. Average total dry mass of *I. virginica* under three fertility rates during a Spring/Summer 2008 Fertility Trial.

	I. virginica		
2008	150/1 N	225/2 N	150/2 N
Total DM (g)	**43.4** ± 0.86	**56.3** ± 3.90	**44.5** ± 5.23

No differences in nutrient uptake efficiency for *I. virginica* (Table 10) were found between treatments. As before, N and P uptake was slow until after the May harvest (Figures 27 and 28), and as in dry mass, no differences in amounts and how N and P were allocated in tissues with the two 150 mg per week treatments.

Table 10. Average nitrogen uptake efficiency (**NUpE**), phosphorus uptake efficiency (**PUpE**) of *I. virginica* under three fertility rates with a 15% target leaching fraction during a Spring/Summer 2008 Fertility Trial.

	I. virginica		
2008	150/1 N	225/2 N	150/2 N
NUpE (%)	**19.7** ± 0.58	**19.2** ± 1.40	**21.2** ± 2.05
PUpE (%)	**27.8** ± 1.13	**23.9** ± 2.23	**28.4** ± 2.71

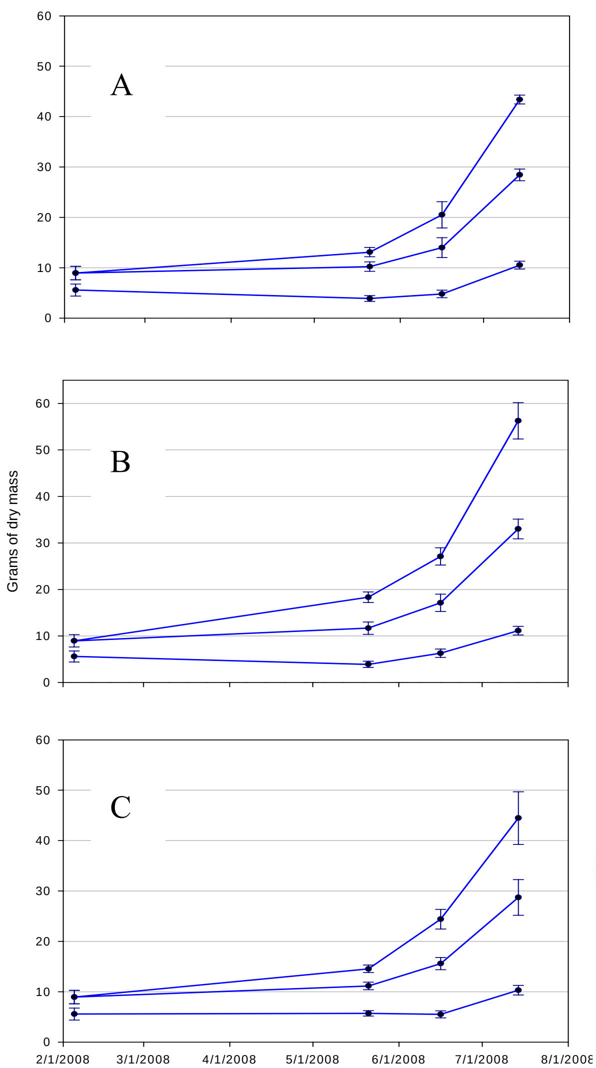

Figure 26 A, B and C. Tissue partitioning graphs o *Itea* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week. The top line represents total dry mass. The area under each line from top to bottom represents leaf, stem and root dry mass. Error bars are 1 SE.

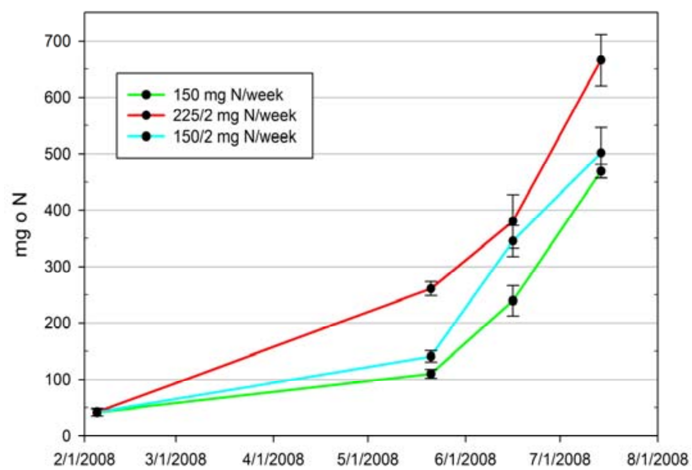

Figure 27. Comparison of average N accumulation in *I. virginica* between three N treatments, 150 mg N per week,, split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. Error bars represent 1 SE.

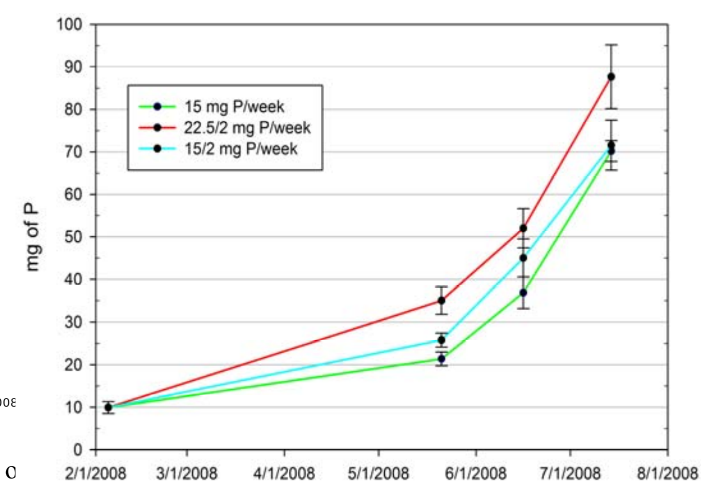

Figure 28. Comparison of average N accumulation in *I. virginica* between three P treatments, 15 mg P per week, split 22.5 mg P per week, and C) split 15 mg P per week over a period of 17 weeks.. Error bars represent 1 SE.

Nutrient partitioning graphs for N (Figure 29 A,B and C) and P (Figure 30 A,B and C) show no differences in the 150 mg per week treatment but significantly more N and especially P being allocated into leaf and stem tissue but not root tissue with the 225 mg N split treatment.

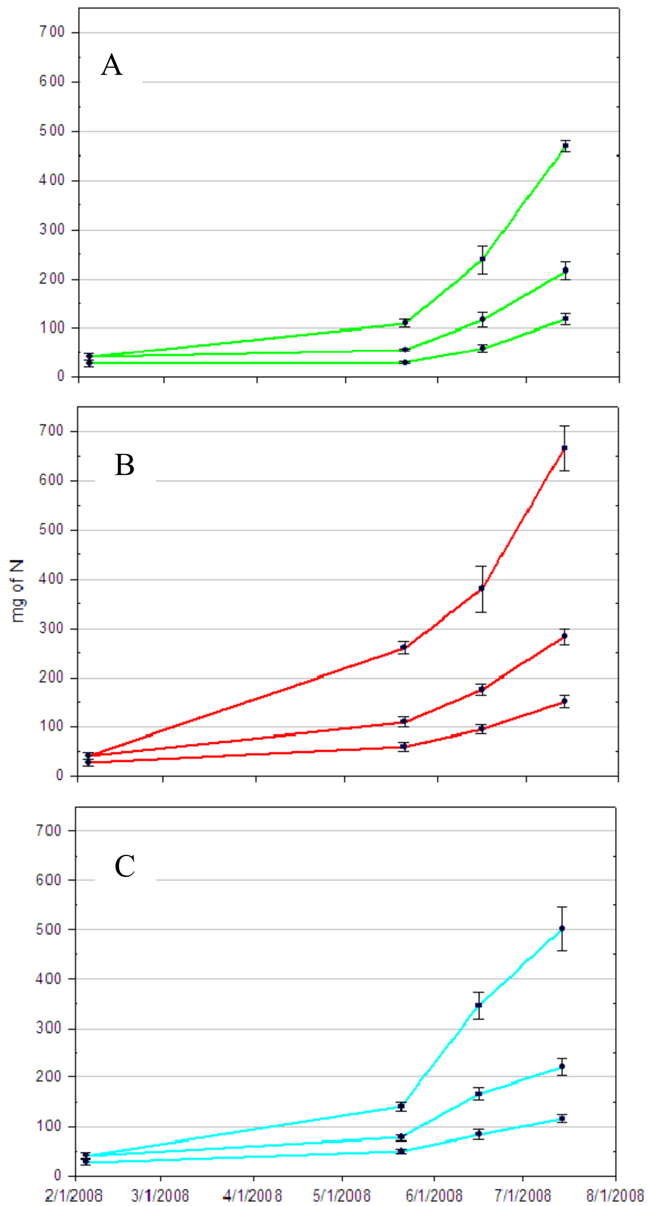

Figure 29 A, B and C. Average tissue N partitioning graphs of *I. virginica* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. The top line represents total N content. The area under each line from top to bottom represents leaf, stem and root N content. Error bars are 1 SE.

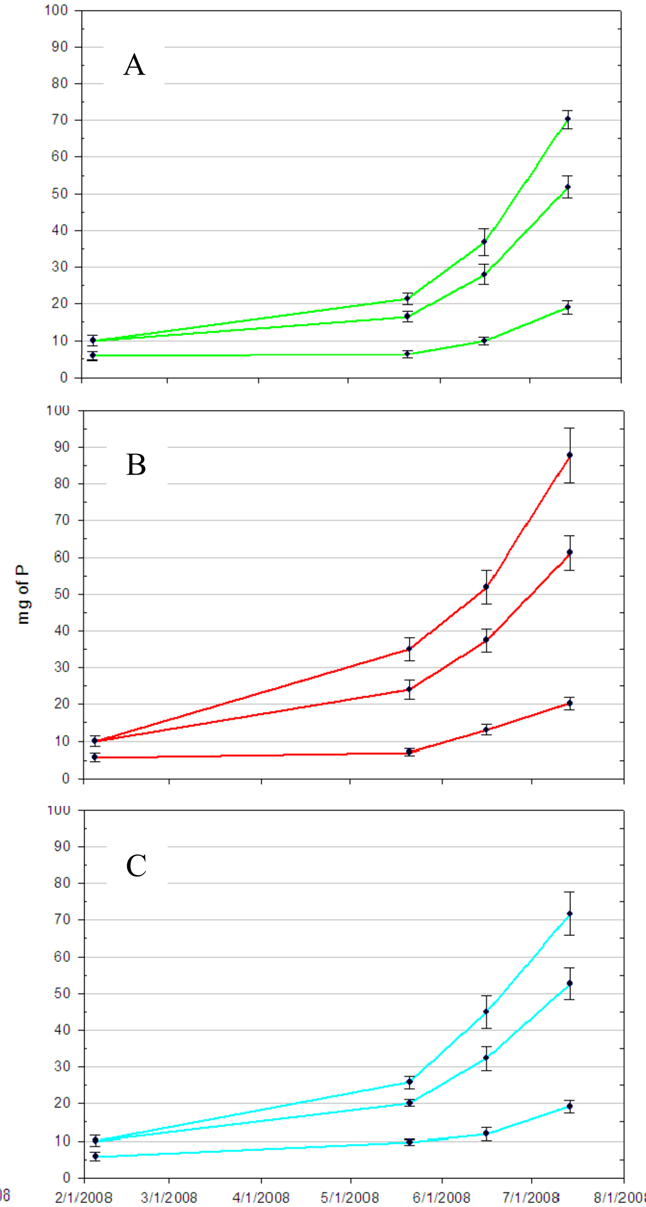

Figure 30 A, B and C. Average tissue P partitioning graphs of *I. virginica* given A) 15 mg P per week, B) split 22.5 mg N per week, and C) split 15 mg P per week over a period of 17 weeks. The top line represents total P content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

Clethra alnifolia

The dry mass comparison of *C. alnifolia* (Figure 31) and (Table 11) shows this species responded more in total growth with split applications than with one weekly nutrient application of 150 mg N per week. Figure 32 A, B, and C show the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. In this study *C. alnifolia* allocated a large portion of biomass to stem tissue in all treatments, with the 225 mg N split application treatment showing greater average stem growth. In this study, there were no differences in treatment response in *C. alnifolia* root growth.

Table 11. Average total dry mass and root dry mass of *C. alnifolia* under two fertility rates and foliar urea during a Spring/Summer 2008 Fertility Trial.

	C. alnifolia		
2008	150/1 N	225/2 N	150/2 N
Total DM (g)	**43.9** ± 3.24	**54.8** ± 3.70	**49.6** ± 1.58

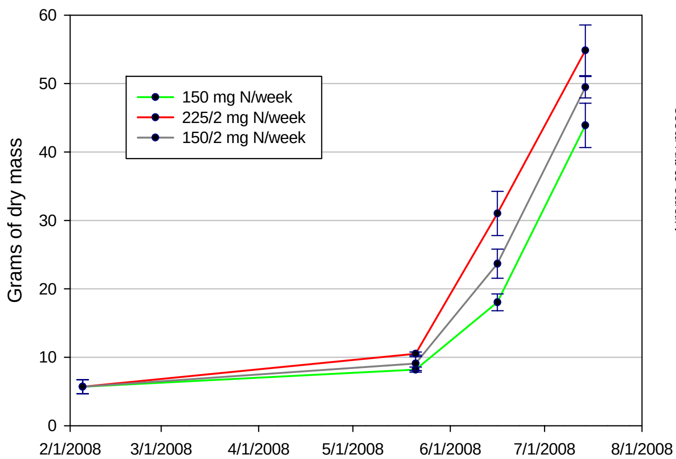

Figure 31. Comparison of average dry mass accumulation in *C. alnifolia* between three nitrogen treatment rates of 150 mg N, and 225 mg N and 150 mg N split applications per week. Error bars represent 1 SE.

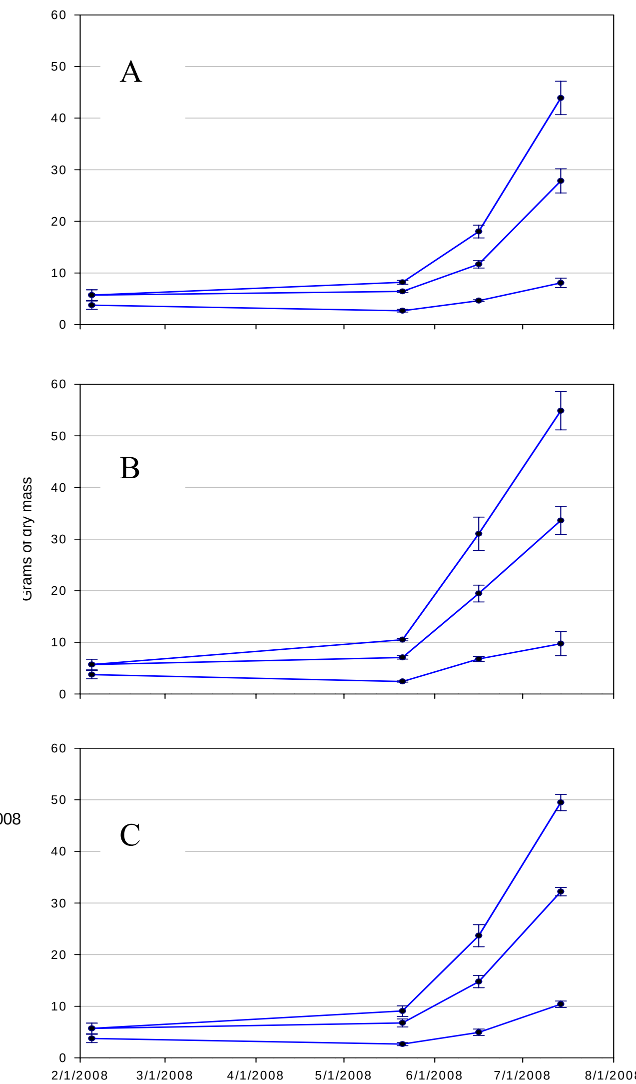

Figure 32 A, B and C. Tissue partitioning graphs of *C. alnifolia* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week. The top line represents total dry mass. The area under each line from top to bottom represents leaf, stem and root dry mass. Error bars are 1 SE.

No differences in nitrogen uptake efficiency between treatments for *C. alnifolia* were found (Table 12). However, P uptake efficiency was less in the single application treatment than the two split treatments. As before, N and P uptake was slow until after the May harvest (Figures 33 and 34), and as in dry mass, no differences existed in amounts and how N and P were allocated in stem and root tissues between the two 150 mg per week treatments. However, plants under the split 225 mg N per week treatment allocated a large portion of N and P to the leaves (Figures 35 A, B and C and 36 A,B and C). The rate of N and P accumulation was nearly linear for all treatments throughout the study after the May harvests. This indicates that *C. alnifolia* could have a well distributed and even nutrient uptake throughout the growing season.

Table 12. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *C. alnifolia* under three fertility rates and a 15% target leaching fraction during a Spring/Summer 2008 Fertility Trial.

	C. alnifolia		
2008	150/1 N	225/2 N	150/2 N
NUpE (%)	**27.2** ± 2.33	**31.7** ± 2.03	**33.9** ± 2.37
PUpE (%)	**31.4** ± 3.05	**36.8** ± 2.38	**39.9** ± 2.14

Nutrient partitioning graphs for N (Figure 35 A,B and C) and P (Figure 36 A,B and C) show no differences in the 150 mg per week treatment but significantly more N and especially P being allocated into leaf and stem tissue but not root tissue with the 225 mg N split treatment.

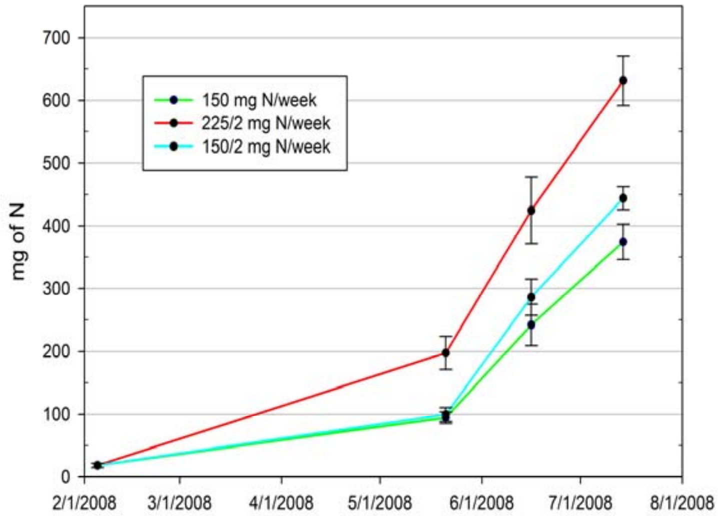

Figure 33. Comparison of average N accumulation in *C. alnifolia* between three N treatments, 150 mg N per week, split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. Error bars represent 1 SE.

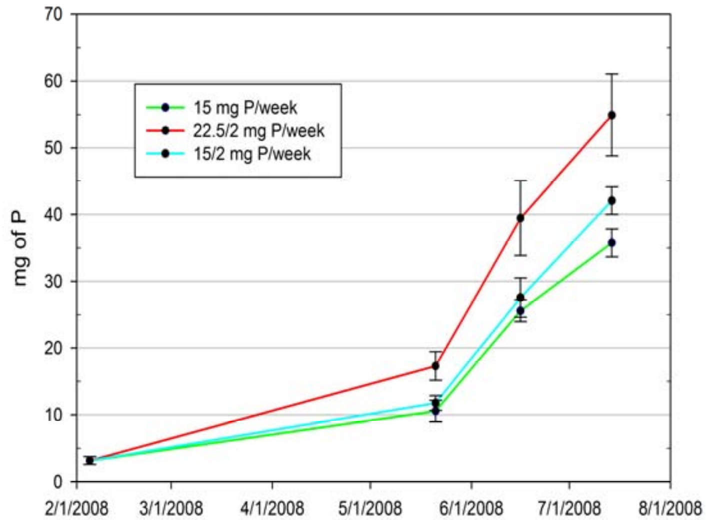

Figure 34. Comparison of average N accumulation in *C. alnifolia* between three P treatments, 15 mg P per week, split 22.5 mg P per week, and C) split 15 mg P per week over a period of 17 weeks. Error bars represent 1 SE.

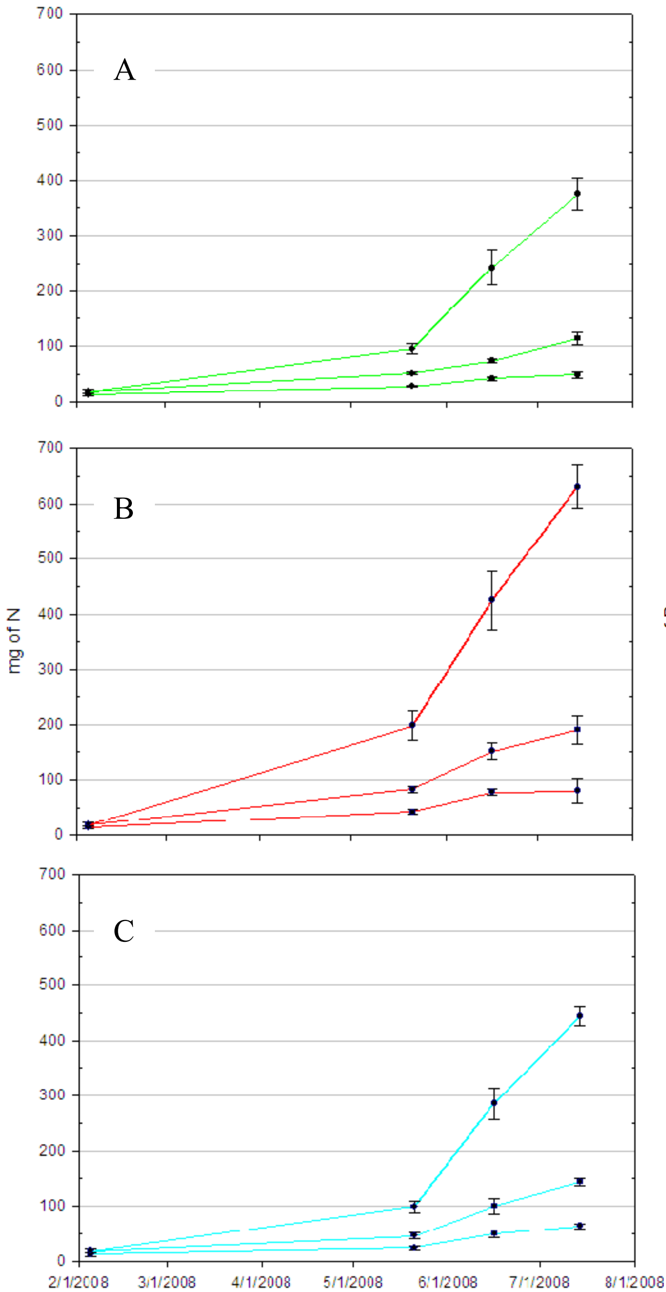

Figure 35 A, B and C. Average tissue N partitioning graphs of *C. alnifolia* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. The top line represents total N content. The area under each line from top to bottom represents leaf, stem and root N content. Error bars are 1 SE.

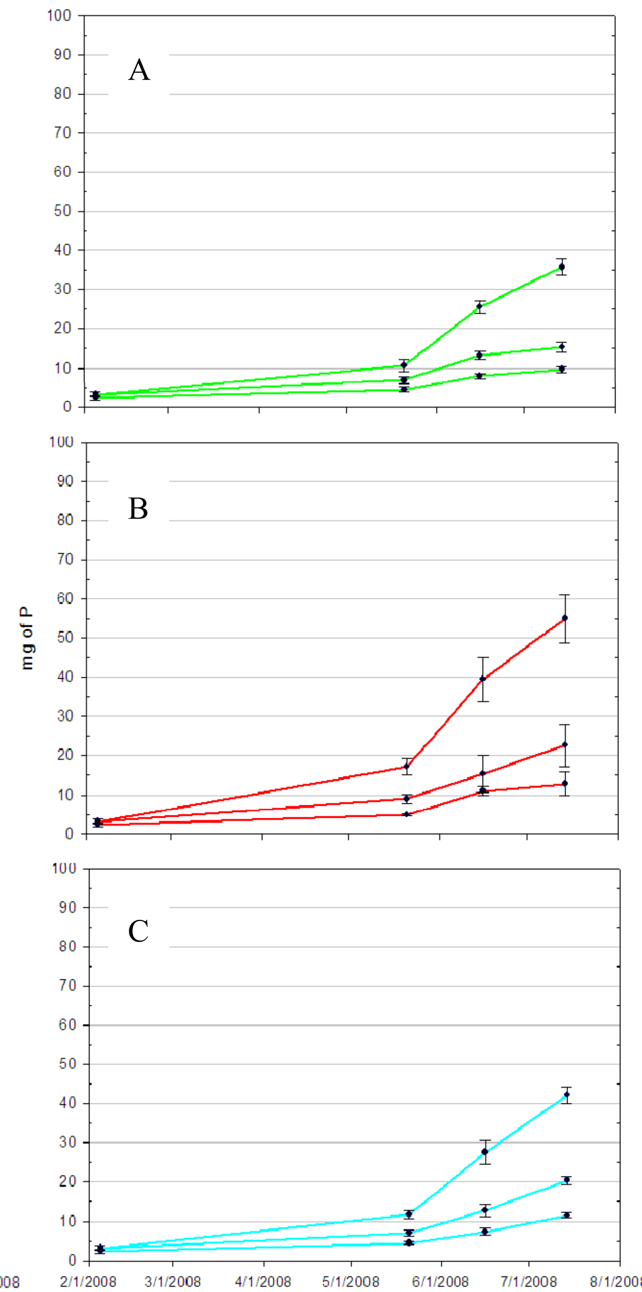

Figure 36 A, B and C. Average tissue P partitioning graphs of *C. alnifolia* given A) 15 mg P per week, B) split 22.5 mg N per week, and C) split 15 mg P per week over a period of 17 weeks. The top line represents total P content. The area under each line from top to bottom represents leaf, stem and root P content. Error bars are 1 SE.

Spartina patens

The dry mass comparison of *S. patens* (Figure 37) and (Table 13) shows a greater treatment response to the split 225 mg N per week treatment over the single 150 mg N per week treatment, but not the split 150 mg N per week treatment. Figure 38 A, B, and C show the dry mass partitioning of shoots and roots as areas under the lines, the top line representing total dry mass. *Spartina patens* did not show greater root growth between treatments. Most of the dry mass is being allocated towards shoot tissue in all treatments. The root mass of *S. patens* looked to be quite extensive throughout the container, visually demonstrating its usefulness as a soil stabilizer on shorelines.

Table 13. Average total dry mass and root dry mass of *S. patens* under two fertility rates and foliar urea during a Spring/Summer 2008 Fertility Trial.

	S. patens		
2008	150/1 N	225/2 N	150/2 N
Total DM (g)	**95.4** ± 8.79	**118.3** ± 7.56	**102.6** ± 8.10

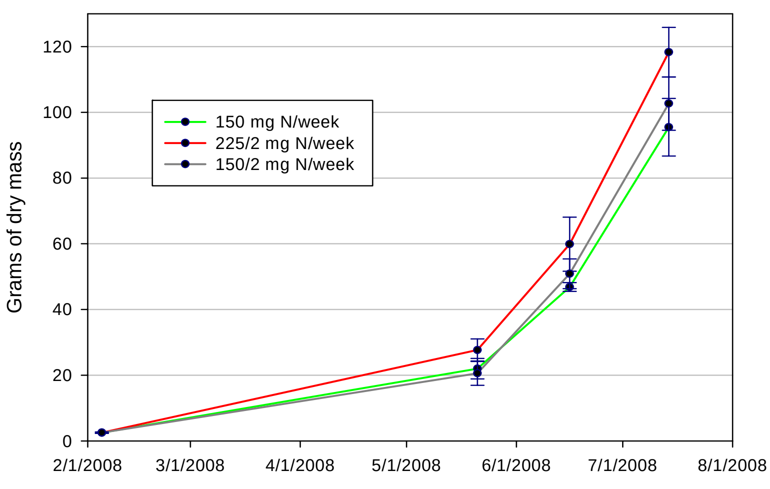

Figure 37. Comparison of average dry mass accumulation in *S. patens* between three nitrogen treatment rates of 150 mg N, and 225 mg N and 150 mg N split applications per week. Error bars represent 1 SE.

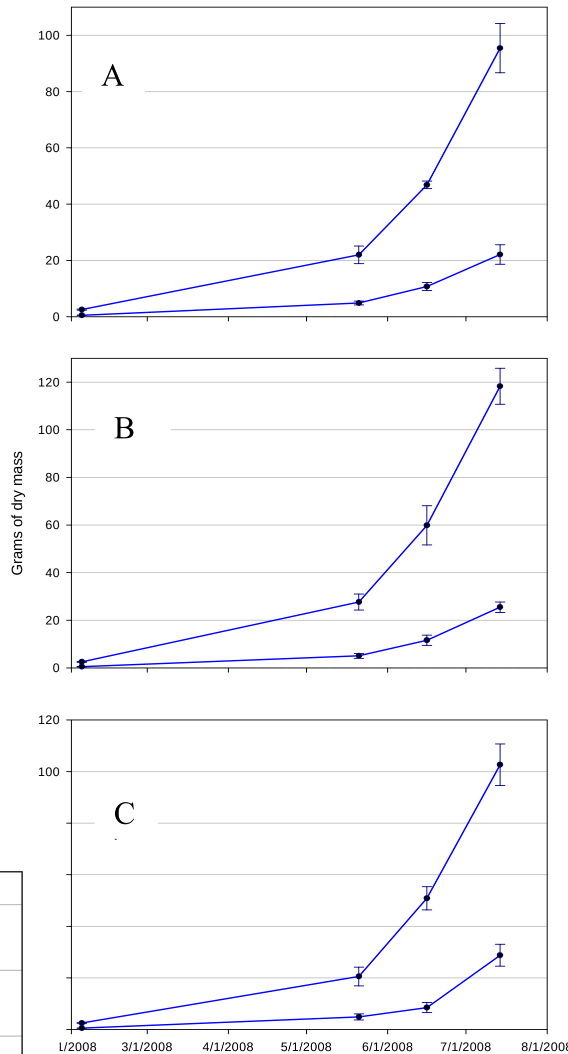

Figure 38 A B and C. Tissue partitioning graphs of *S. patens* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week. The top line represents total dry mass. The area under each line from top to bottom represents shoot and root dry mass. Error bars are 1 SE.

Table 14 shows N and P uptake efficiency in *S, patens*. Higher efficiencies were obtained compared to the 2007 study. Nitrogen and P uptake efficiencies were not different between treatments in this study.

Table 14. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *S. patens* under three fertility rates and a 15% target leaching fraction during a Spring/Summer 2008 Fertility Trial.

	S. patens		
2008	150/1 N	225/2 N	150/2 N
NUpE (%)	**41.1** ± 10.0	**42.37** ± 3.33	**34.9** ± 2.66
PUpE (%)	**38.2** ± 3.26	**36.8** ± 2.38	**43.6** ± 3.44

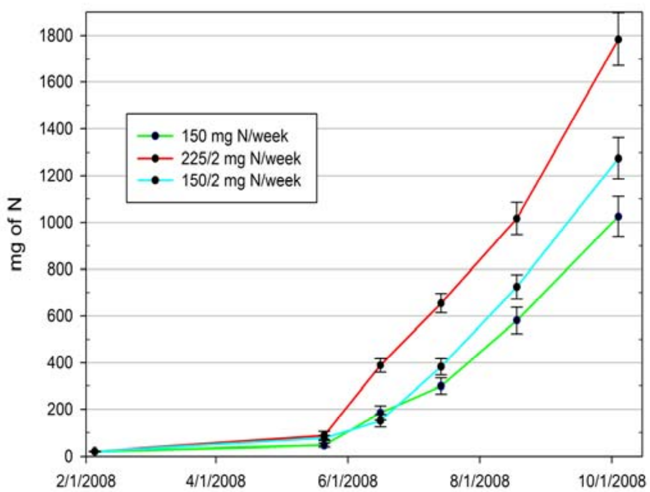

Figure 39. Comparison of average N accumulation in *S. patens* between three N treatments, 150 mg N per week, split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. Error bars represent 1 SE.

Content of N and P (Figures 39 and 40 respectively) in *S. patens* between the single and split 150 mg N per week treatments were not different throughout the study period, but became different with the split 225 mg N per week treatment soon after study initiation. The plant utilized the two 150 mg N and 15 mg P treatments rather equally regardless of the single or split application method.

Nitrogen and P partitioning graphs (Figure 41 A, B and C and Figure 42 A, B, and C, respectively) show very similar uptake and partitioning patterns between the 150 mg N per week treatments however, 225 mg N treatment shows that at high nutrient levels, *S. patens* allocates N and P to the shoot. There was no difference between treatments in the amount of N and P allocated to the root systems of plants. Since there is still allocation of nutrients to the shoots, this may indicate that luxury nutrient consumption has not been reached and that the plant is can still assimilate higher nutrient rates.

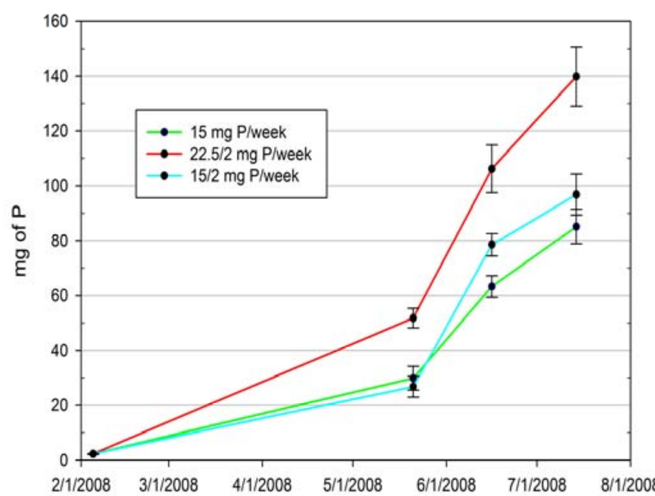

Figure 40. Comparison of average P accumulation in *S. patens* between three P treatments, 15 mg P per week, split 22.5 mg P per week, and C) split 15 mg P per week over a period of 17 weeks. Error bars represent 1 SE.

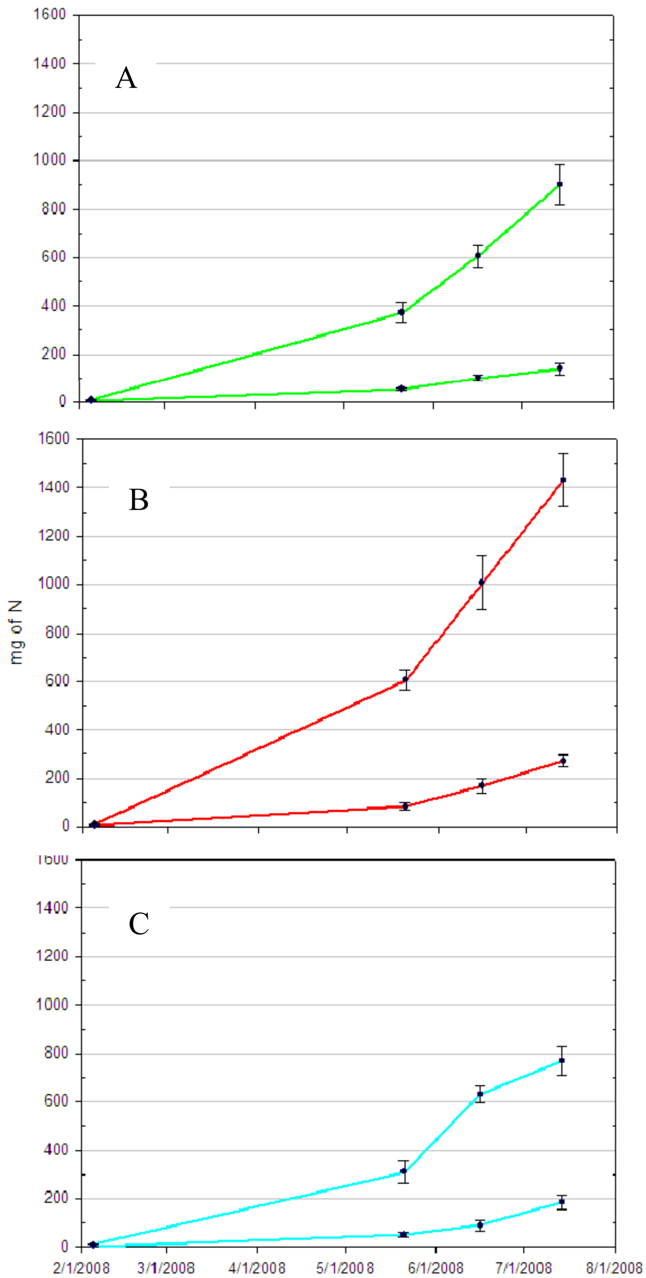

Figure 41 A, B and C. Average tissue N partitioning graphs of *S patens* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week over a period of 17 weeks. The top line represents total N content. The area under each line from top to bottom represents shoot and root N content. Error bars are 1 SE.

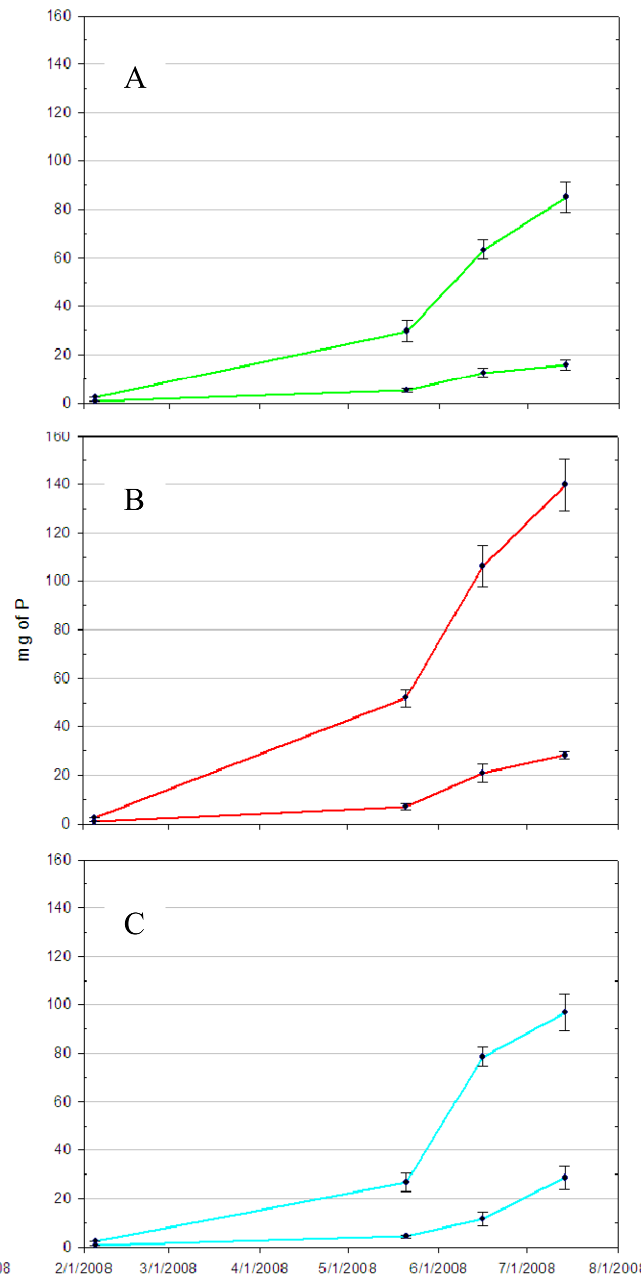

Figure 42 A, B and C. Average tissue P partitioning graphs of *S patens* given A) 15 mg P per week, B) split 22.5 mg N per week, and C) split 15 mg P per week over a period of 17 weeks. The top line represents total P content. The area under each line from top to bottom represents shoot and root P content. Error bars are 1 SE.

Photinia melanocarpa

Average total dry mass of *P. melanocarpa* (Table 15) shows that this species responded with greater biomass to the split application of 225 mg per week than either the single or split 150 mg N application. Differences in growth between the rates were manifested by early June (Figure 43). Figure 44 A, B, and C shows the dry mass partitioning of leaves, stems and roots as areas under the lines, the top line representing total dry mass. Greater dry mass was allocated towards stem tissue in the treatments than other species. Root growth in *P. melanocarpa* was no different between the rates. Plants responded to the 225 mg/week N application with greater leaf and stem growth. *Photinia melanocarpa* showed greater response in biomass toward split applications compared to one weekly application.

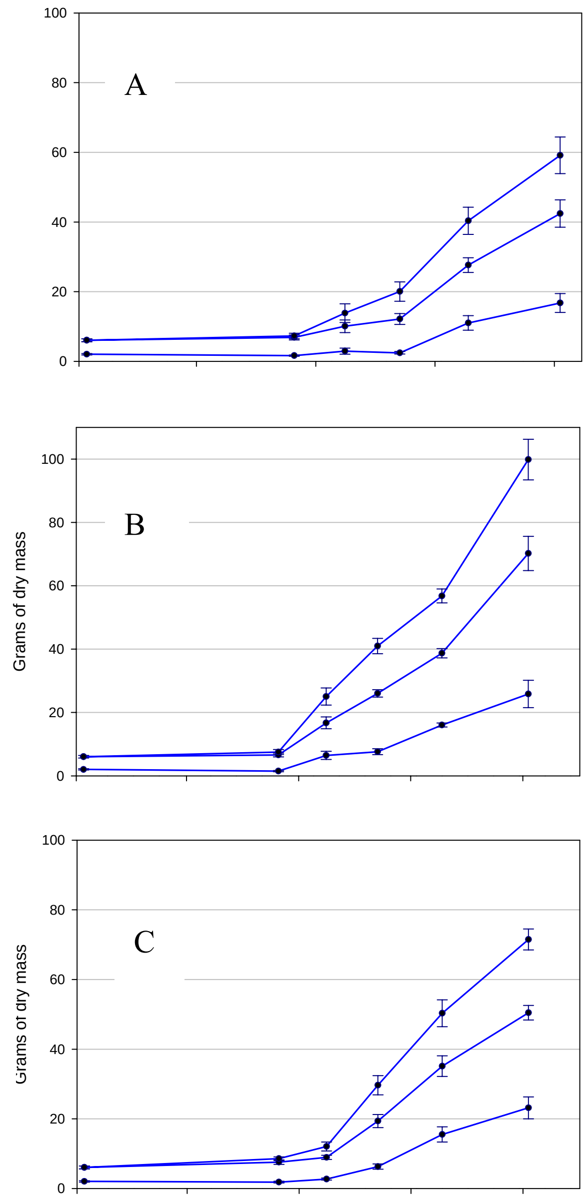

Figure 44 A ,B and C. Tissue partitioning graphs of *P. melanocarpa* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week. The top line represents total dry mass. The area under each line from top to bottom represents leaf, stem and root dry mass. Error bars are 1 SE.

Table 15. Average total dry mass and root dry mass of *P. melanocarpa* under two fertility rates and foliar urea during a Spring/Summer 2008 Fertility Trial.

	P. melanocarpa		
2008	150/1 N	225/2 N	150/2 N
Total DM (g)	**59.1** ± 5.27	**98.8** ± 6.41	**71.5** ± 2.99

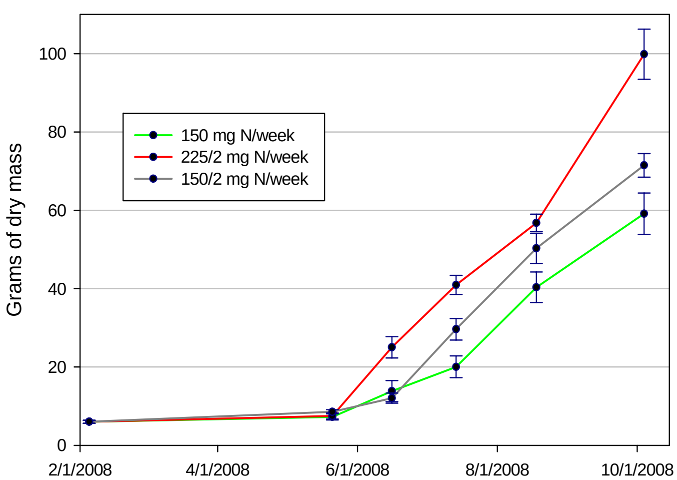

Figure 43. Comparison of average dry mass accumulation in *P. melanocarpa* between three nitrogen treatment rates of 150 mg N, and 225 mg N and 150 mg N split applications per week. Error bars represent 1 SE.

Table 16 compares average N and P uptake efficiency between the rates. In this study there was no difference in N uptake efficiency between treatments, however, P uptake efficiency was significantly greater with the split application of 150 mg N per week than the single application. There was no difference in the split 225 mg N per week treatment and the 150 mg N per week treatments. Figures 45 and 46 show N and P content significantly greater with the split 225 mg N per week treatment and no difference in the 150 mg N per week treatments.

Table 16. Average nitrogen uptake efficiency (**NUpE**) and phosphorus uptake efficiency (**PUpE**) of *P. melanocarpa* under two fertility rates and foliar urea and a 15% target leaching fraction during a Spring/Summer 2008 Fertility Trial.

	P. melanocarpa		
2008	150/1 N	225/2 N	150/2 N
NUpE (%)	**27.2** ± 2.33	**31.7** ± 2.03	**33.9** ± 2.37
PUpE (%)	**31.4** ± 3.05	**36.8** ± 2.38	**39.9** ± 2.14

As in the 2007 Greenhouse studies, *P. melanocarpa* evenly distributed N and P in tissues regardless of rate, compared to other species (Figure 47 A, B and C and Figure 48 A, B and C). A significantly greater content of N and P was accumulated in the 225 mg N split rate, and it is likely that *P. melanocarpa* would have tolerated a higher fertility rate since there was no plateau in biomass production.

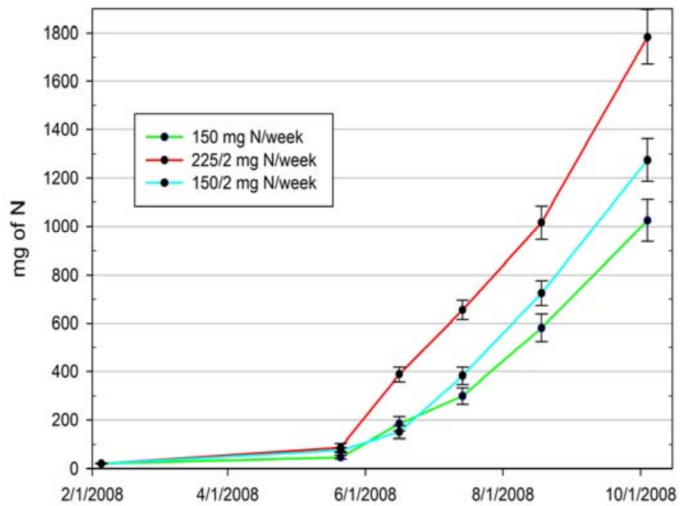

Figure 45. Comparison of average N accumulation in *P. melanocarpa* between three N treatments, 150 mg N per week, split 225 mg N per week, and C) split 150 mg N per week over a period of 29 weeks. Error bars represent 1 SE.

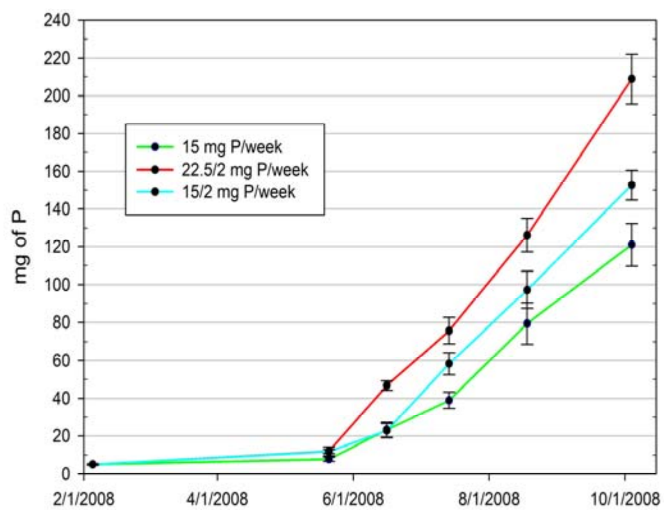

Figure 46. Comparison of average N accumulation in *P. melanocarpa* between three P treatments, 15 mg P per week, split 22.5 mg P per week, and C) split 15 mg P per week over a period of 29 weeks. Error bars represent 1 SE.

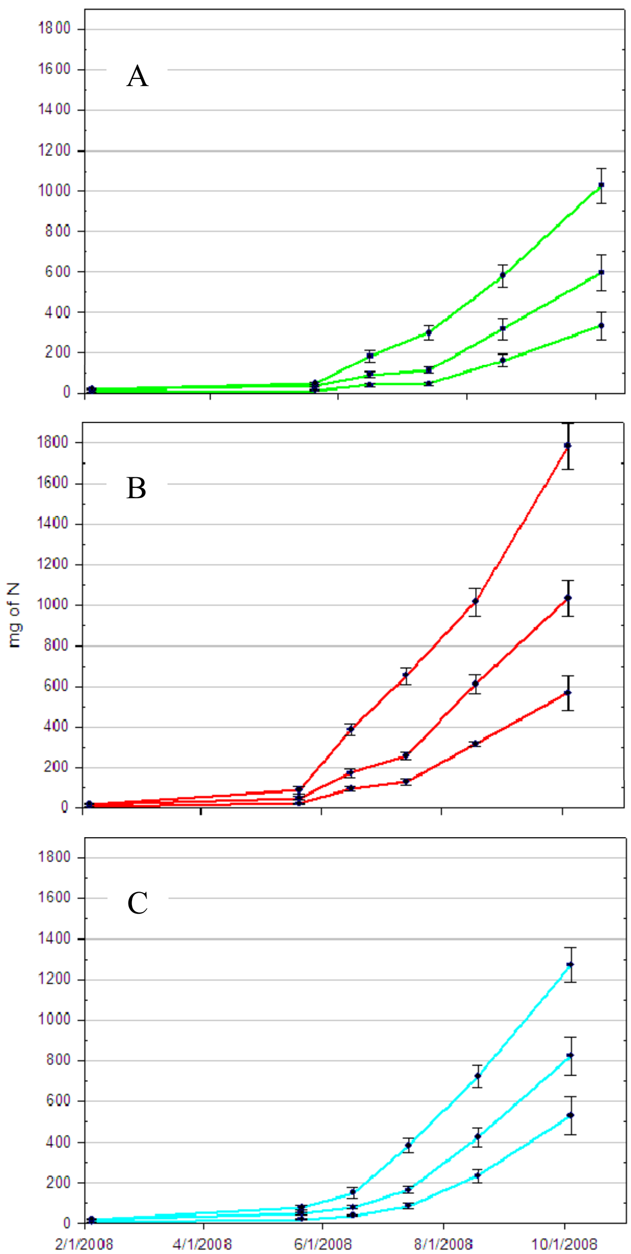

Figure 47 A, B and C. Average tissue N partitioning graphs of *P. melanocarpa* given A) 150 mg N per week, B) split 225 mg N per week, and C) split 150 mg N per week over a period of 29 weeks. The top line represents total N content. The area under each line from top to bottom represents stem and root N content. Error bars are 1 SE.

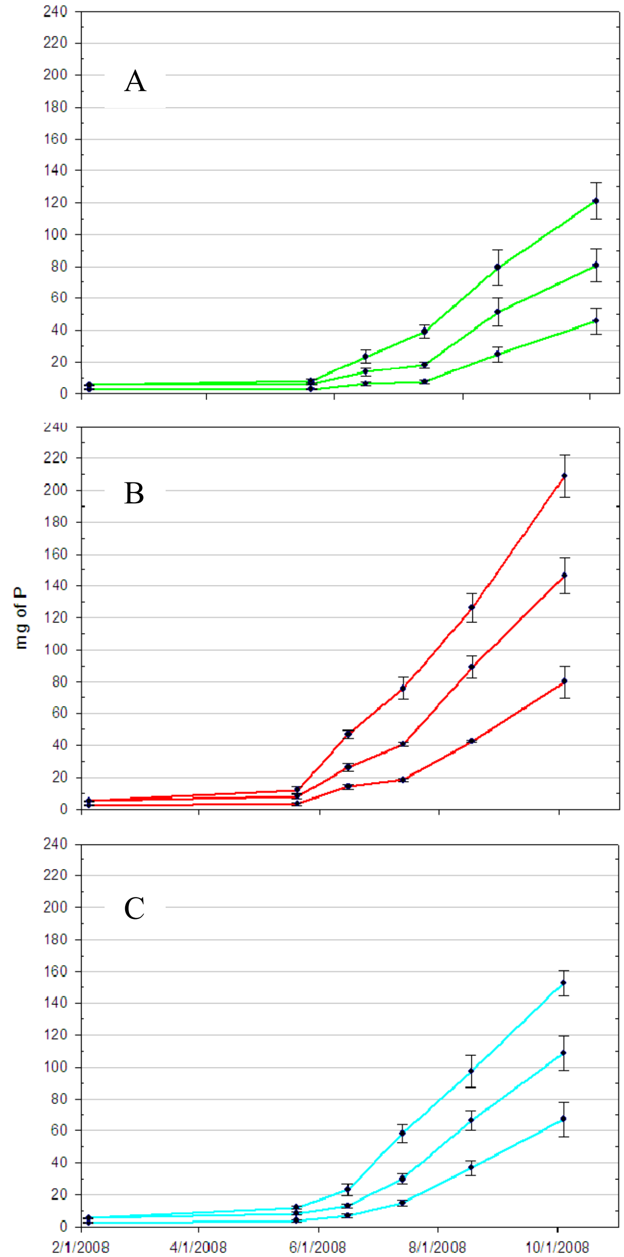

Figure 48 A, B and C. Average tissue P partitioning graphs of *P. melanocarpa* given A) 15 mg P per week, B) split 22.5 mg N per week, and C) split 15 mg P per week over a period of 29 weeks. The top line represents total P content. The area under each line from top to bottom represents stem and root P content. Error bars are 1 SE.

Greenhouse Fertility Studies Summary

The species studied in these two growing seasons of greenhouse research responded best to the high fertility treatments. Anecdotal information about native plant species nutrient efficiency suggests that each would have responded equally at least to the high and medium treatment rates. However, these species exhibited uptake efficiencies not significantly different between fertilizer rates, unlike other nutrient-rate research where higher rates equated to lower efficiencies (Ristvey et al., 2007; Ristvey et al., 2004; Cabrera, 2003). Also, differences in the transformed data of *P. melanocarpa* and *S. patens* root dry mass suggested that roots responded better to higher fertilization rates. This again, is different than other studies showing root mass greater with lower nutrient rates (Ristvey et al., 2007; Lynch et al., 1991; Yeager and Wright. 1981).

Unfortunately the foliar urea treatment was limiting for all species and less biomass was acquired by plants under this treatment. This may be because of the amount of N available to the plants was far below the amount delivered in the other treatments, or that the plants did not utilize the applied urea. Also, the foliar urea treatment did not provide enough N to elicit root growth. In any case, the use of foliar urea on these plants does not seem feasible.

In the 2008 study, all plants exhibited greater growth with split applications of the high 225 mg N per week treatment. Except for *S. patens*, there was little difference in dry mass between the two 150 mg N per week treatment, regardless of application method, meaning that split applications at this rate did not prove to be a more efficient method applying nutrients. The 150 mg N and 15 mg P treatment can be considered a medium industry rate for a #2 container in terms of controlled release fertilizer (CRF) application, even though nutrients were applied via soluble application. One could say the incremental application of soluble fertilizer is likened to the slow release of CRF fertilizer through time. Based on previous studies (Ristvey et al., 2007; Ristvey et al., 2004; Cabrera, 2003) this medium industry rate is sufficient for many species. In the 2007 study, 75 mg N per week was limiting, but two applications of 75 mg N per week, were enough to improve the growth response. It seems if the upper limit of fertility in these plants was not reached in the 2008 study based on the split 225 mg N per week treatment as no growth plateau was noted, however, because this rate had a high soluble salt (nutrient) content, a higher rate would have been difficult to achieve in two applications per week without damaging roots. It suggests that the species investigated would have been able to utilize more high N applications more often during the week, however, monitoring the potting substrate for increase residual salts and managing leachates would be necessary.

From these studies, fertility recommendations can be made for these species and similar plants that would suggest the use of rates slightly higher than medium industry rates to improve biomass production. For instance, *P. melanocarpa* in the 2008 study increased its biomass by 21% in a split 150 mg N per week than in one application alone. By applying a 225 mg N per week split rate, top-growth biomass increased an additional 38%. The plants that received additional fertilizer would be considered more marketable, moving them from production to sale in shorter time. It would make more economic sense if these plants could be grown with higher fertilizer rates in less time, providing less residence time in the nursery. While fertilizer was applied in a soluble form with water, most nurseries' primary method of fertilization is now through controlled release fertilizer (CRF). These rates of soluble fertilizer utilized in this study can be translated relatively easily to CRF rates. However, any recommendations based on these results would be tempered with proper management of irrigation regardless of the fertility rate being applied.

Field Irrigation Studies – Wireless Node System/Moisture Sensors

Further investigation into sensor-driven irrigation revealed a wireless communication system being developed by Carnegie Mellon University Robotics Institute (CMU). This system, called Mobius promised to be inexpensive and relatively user-friendly for growers. With additional funds raised in 2007, a Wireless Node System with integrated EcH_2O moisture sensors (Decagon Devices, Pullman, WA) were successfully retrofitted into the irrigation study portion of this project. The research using a wireless irrigation control system would allow comparison of the best management practice of time-controlled cyclic irrigation with sensor controlled irrigation.

Due to design complications with the Cellugro system, another growing system was fabricated to accommodate the field irrigation research portion of this study which instead incorporated raised platforms. This change did not compromise the character of the research or quality of the data.

Because of a funding delay in the Field Irrigation studies, a one-year no-cost extension was requested and granted in 2007 to attain at least two years of growing season data.

Figure 50. The AgroEcology, Inc. funded research project with wireless sensor network nodes and probes in place. Note the wireless node in the foreground.

Field Irrigation Studies Methods

This research was performed at the University of Maryland's Wye Research and Education Center, Experimental Nursery in Queenstown MD. Specifically, the objectives of this part of the study were to test and determine the efficiency of a wireless, automatic moisture-monitoring/control system for irrigation compared to cyclic irrigation, which was determined to be a best management practice (BMP) for increase irrigation efficiency (Yeager et al., 2007; Tyler et al., 1996a; Tyler et al., 1996b; Beeson and Haydu, 1995). Cyclic irrigation entails increasing the number of irrigation events, but of shorter duration during the day time. The wireless monitoring/control system utilizes capacitance probes to determine the moisture content of the soilless substrate, and relating that moisture content to plant available water which can vary between different substrates. The relation between moisture content and plant available water is determined through the calibration of sensors to different soilless substrates. Calibration procedures are outlined in Arguedas et al., 2007. Briefly, the wireless node network system was developed by CMU. Each year, the wireless node network, software and firmware were updated to the newest generation from CMU. Each node had the capacity for attaching 5 analog and 5 digital sensors in any combination of soil moisture and electrical conductivity sensors, soil and air temperature, relative humidity, tipping rain gauge and light (photosynthetically-active radiation) sensors, according to the specific sensing requirements of the grower. In this project, Decagon Devices (Pullman, WA) moisture sensors were utilized for monitoring moisture content in soilless substrates and controlling irrigation. In the 2009 studies, new updated sensors (Model 10 HS) were utilized.

The experimental design consisted of 24 elevated 1.2 meter square tables or platforms used as plots. In each plot were 25 plants (20 plants in 2009) in two gallon containers. Each plot had its own separate micro-irrigation system utilizing spray stakes (Netafim Tel Aviv, Israel) which evenly distributed irrigation water over the surface of the substrate in the container. Flow meters were placed on each platform to measure volume of water applied at each irrigation event throughout the growing period. Additionally, all water draining from the platform was captured and measured with another flow meter, so that both water input and runoff from each platform was tracked. In 2009, that runoff from each platform was also analyzed for N and P content.

Platforms were assigned with one of the two irrigation systems to evenly distribute treatments over the study area. Half (12) of the platforms were controlled by a single irrigation timer, set according to a best-guess estimate about plant water requirements. The 12 CMU nodes determined the irrigation scheduling based on moisture sensor output. To each node were connected 4 capacitance or moisture sensors, each placed in random containers on the platform. Set points, determined by calibrating the probes to the water content in the potting substrate, were used to turn irrigation on and off from the node. Probe data, taken once every 5 minutes, were averaged by the node firmware. If the average value was at or below the "low" set point, the irrigation was turned on until the "high" setpoint was reached. The goal was to maintain plant available water while minimizing leachate. Since the output of the spray stakes was relatively high and since we were irrigating plants in a relatively small container with a sensors/node system that requires time to cycle through measurements, a micro-pulsed irrigation routine was developed. The irrigation was applied for a time between 2 and 5 seconds, with an interval that could be adjusted between measurements for water to percolate through the substrate. At the end of this interval, another probe measurement was taken and averaged. The nodes continued to cycle irrigation until the high set point was reached, at which point the irrigation was turned off until the next time the low set point was reached.

2007 Field Irrigation Studies

Three of the four species in the greenhouse experiments were being utilized for the field studies including *C. alnifolia*, *I. virginica*, and *P. melanocarpa.* The forth was *Viburnum prunifolium*. In the weeks of operation from late September into October, the system performed well, irrigating when the "on" set-point was reached and turning off irrigation before containers were up to water holding capacity. Cyclically timed irrigation was set for three times a day, delivering an average of 1000 ml of water per plant per day for an average of about 30 liters per plant during the month with about 15% target leaching fraction from the pots. By comparison the wireless network-controlled irrigation averaged less than one liter per plant throughout the month without leaching. These preliminary results suggest that this wireless sensor system can control irrigation, and minimize leaching better than a recommended BMP.

The first month of data showed that the micro-pulse routine was more effective in managing water use compared to cyclic irrigation. During this month, cyclic irrigation was adjusted to deliver approximately one liter of water per day to each plant. The sensor-controlled irrigation applied water based on matrix potential or the amount of water available to the plant. Over thirty days between September 25 and October 30 of 2007, the sensor-controlled irrigation had applied approximately one liter of water to each plant, compared to 30 liters per plant applied by the time irrigation system.

2008 Field Irrigation Studies

One of the most important parts of this research was the development of a Graphic User Interface (GUI). For this year, a prototype GUI was developed for visual interpretation and real-time monitoring of moisture status in plant containers (see Figure 51). The GUI development is

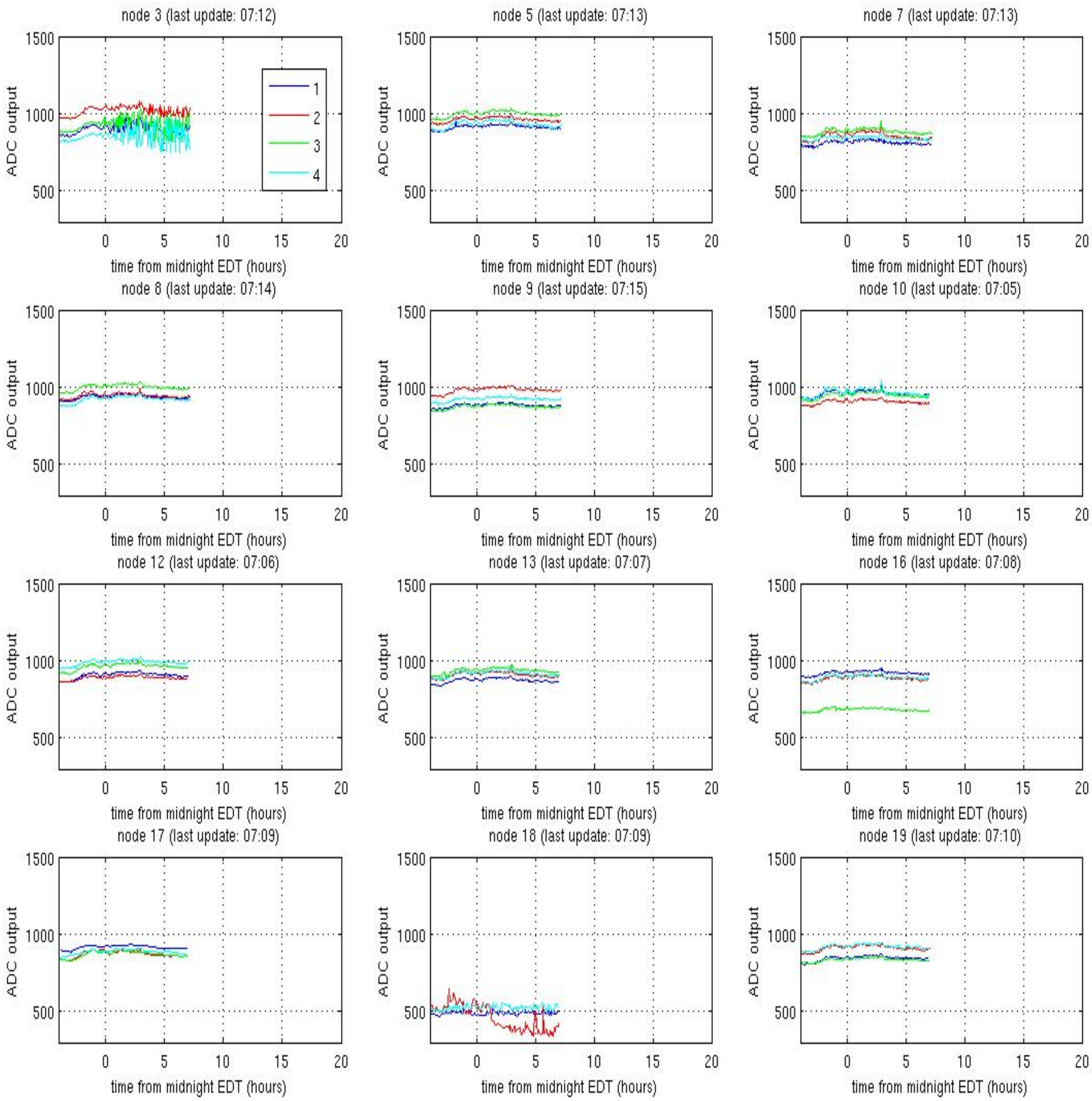

Figure 51. Graphic User Interface for each of the twelve nodes at the Wye Research Experimental Nursery. Graphs show time (24 hours) vs. sensor output. Sensor output can be interpreted as moisture content in containers. Graphs show output for four sensors in each of the nodes.

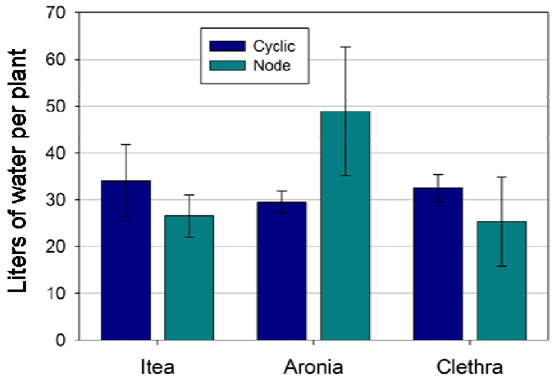

Figure 52. Comparison of average water applied in liters between cyclic and node (sensor) controlled irrigation by species, during the 2008 season. Error bars represent 1 SE.

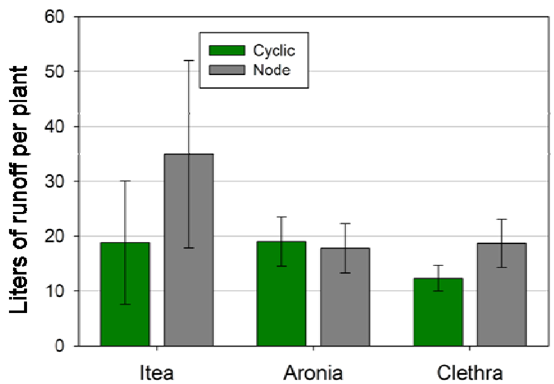

Figure 53. Comparison of average runoff in liters between cyclic and node (sensor) controlled irrigation by species during the 2008 season. Error bars represent 1 SE.

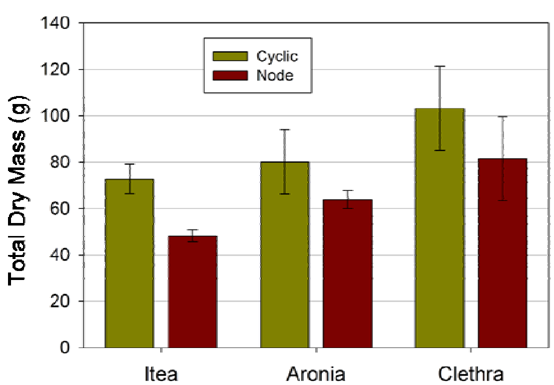

Figure 54. Comparison of average total dry mass in g between cyclic and node (sensor) controlled irrigation by species at the end of the 2008 season. Error bars represent 1 SE.

critical for Green Industry adoption of this system. The interface makes this system practical and user friendly.

However, communication with the wireless system established at Wye was dependent upon reliable wi-fi signals, which throughout the summer of 2008 were intermittent. Irrigation set-points could not be adjusted on a regular basis, and the efficiency of irrigation control system suffered. The overall results showed that the wireless control system could match or do slightly better in water use than a very conservative cyclic irrigation management program. Occasionally one node or probe would malfunction and the system would over irrigate a platform, inflating leachate volumes and creating high variability in the data. Because of this variability, averages that look different are statistically insignificant.

Figure 52 compares the average total amount of water applied by either cyclic or sensor controlled irrigation to each plant, by species in the 2008 growing season. Statistical analysis required that the irrigation data needed transformation because of unequal variances. No differences existed between the transformed data. Figure 53 compares the average total amount of water runoff by either cyclic or sensor controlled irrigation to each plant, by species in the 2008 growing season. No differences existed between cyclic and sensor irrigation by species.

Finally, there was no difference in total dry mass between treatment in *P. melanocarpa (Aronia)* or *C. alnifolia* (Clethra), but *I. virginica* (Itea) showed sensitivity to less water by producing less biomass with less water (Figure 54).

2009 Field Irrigation Studies

During the 2009 season, software and firmware design improvements with a new iteration of the sensor node and sensors were introduced into the research study. Included in this was new controlling software that allowed the user to control individual nodes, specifically to adjust set-points. Additionally, the wi-fi system was corrected for the 2009 study period, but the wireless nodes began to have problems with inter-node communications, this time due to firmware within the node and base-station hardware. The planned graphic user interface was not employed because of constant malfunctions. Because of these technical issues the nodes could not consistently control irrigation.

Figure 55 compares the average total amount of water applied by either cyclic or sensor controlled irrigation to each plant, by species in the 2009 growing season. Statistical analysis required that the irrigation data needed transformation because of unequal variances. Because of the malfunctioning nodes in 2009, significant differences existed between all treatments with all species as sensor controlled irrigation often over applied water after periods of no irrigation application. Figure 56 compares the average total amount of water runoff by either cyclic or sensor controlled irrigation to each plant, by species in the 2009 growing season. As in the 2008 season, no significant differences existed between cyclic and sensor irrigation by species. As shown in Figure 57, there was no difference in total dry mass between treatment in *P. melanocarpa* (Aronia) or *C. alnifolia* (Clethra), but *I. virginica* (Itea) produced less biomass with the sensor controlled system. This sensitivity with *I. virginica* was captured in the 2008 and 2009 seasons and *I. virginica* may be more sensitive to irrigation volumes. Set points can be adjusted for water requirements of different species.

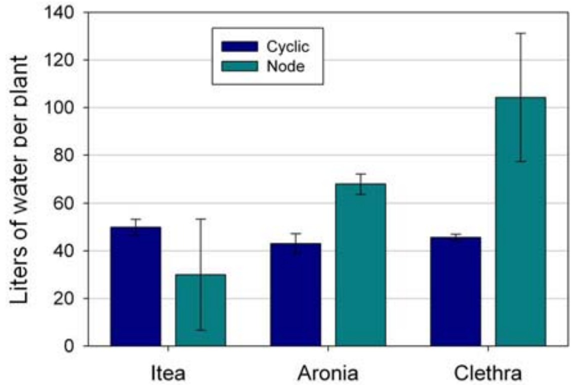

Figure 55. Comparison of average water applied in liters between cyclic and node (sensor) controlled irrigation by species, during the 2009 season. Error bars represent 1 SE.

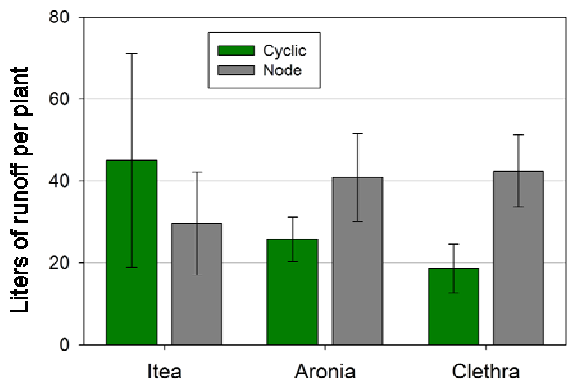

Figure 56. Comparison of average runoff in liters between cyclic and node (sensor) controlled irrigation by species during the 2009 season. Error bars represent 1 SE.

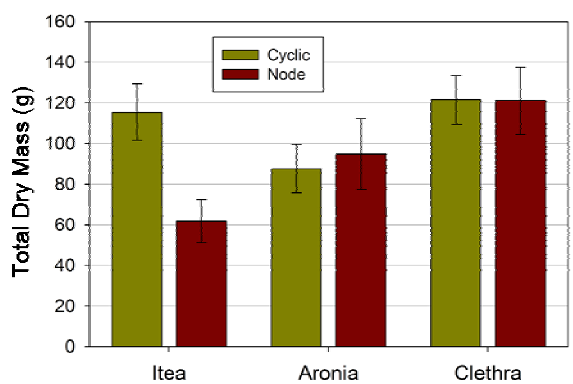

Figure 57. Comparison of average total dry mass in g between cyclic and node (sensor) controlled irrigation by species at the end of the 2009 season. Error bars represent 1 SE.

2009 Nutrient Runoff Capture

Runoff nutrient content from irrigation plots were measured in the 2009 growing season. Runoff was analyzed for N and P concentration, normalized for runoff volume and presented as total N and P content. This total N and P content was then compared between plants and irrigation methods in Figures 58 and 59 below. No differences in N content in runoff were found between irrigation methods or species. The only differences found in P content of runoff were between irrigation methods in *I. virginica*. Because high variability existed in irrigation volumes as seen in the standard errors (SE), N and P content were equally variable. As this system is improved, differences in the volume of irrigation runoff will have direct effects reducing N and P runoff.

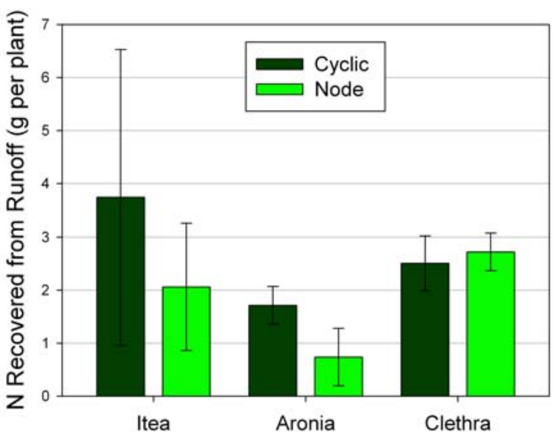

Figure 58. Average N content in runoff between species and irrigation method of either node (sensor) controlled irrigation or timed irrigation.

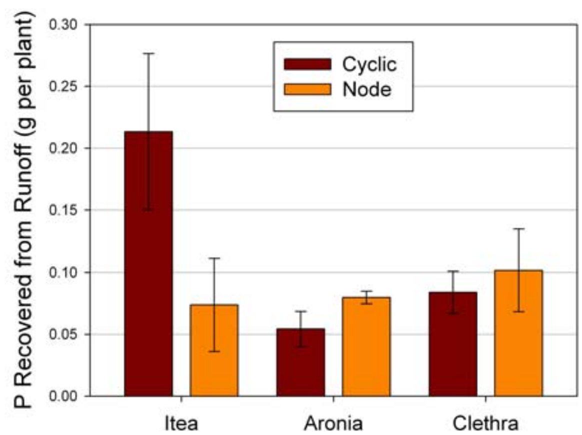

Figure 59. Average P content in runoff between species and irrigation method of either node (sensor) controlled irrigation or timed irrigation.

Irrigation Research Summary

The 2009 season showed that the wireless node system was prone to malfunctions, however further lessons were gained from the 2009 study period. The base station and node firmware is being updated for the 2010 growing season and a successful bid for a multi million dollar United States Department of Agriculture Special Crops Research Initiative grant titled "*Precision Irrigation and Nutrient Management for Production Nursery, Greenhouse and Green Roof Systems, using Wireless Sensor Networks*" has given this research increased capital for problem solving and technical troubleshooting.

Additional Research with Alternative Crops

Fruit Yield Trials

Additional research on *P. melanocarpa* has been undertaken at the Wye Research and Education Center to assess the effects of fertilizer inputs on fruit yield. This research was not funded by Agro Ecology Inc., but since this species is the most promising alternative crop studied in this project, this information was included to show the synergistic research and extension programming developed since April 2006. One hundred young *P. melanocarpa* plants were planted in April 2006 at the Wye Research and Education Center. Since that time yield studies based on organic production practices and fertility rates have yielded some interesting information about *P. melanocarpa* fertility and fruit yield. The fruit yield studies have shown that once plants are placed in the ground, there is no difference in yield between plants given 3g or 7g rate of N throughout three growing seasons (Ristvey and Tangren 2009). Further research into fertility rates will continue. The plants yield fruit (approximately 2 kg per plant) within the second full growing season. If planted in the spring, plants will start to yield the second summer. Within 5 years, plants may yield between 4 and 7 kg of berries per plant. Fertility research will continue on *P. melanocarpa* at Wye Research and Education Center.

Extension Outreach and Impacts

This Agro-Ecology Inc. funded research program was designed around an Alternative Crop Extension and Sustainability Program. The first two alternative crop presentations were given at the 2006 Mid Atlantic Crop Management Program and the Delaware Crop School in January of 2007. The presentation introduced two species for potential fruit production, one of which is being studied in this research project (*P. melanocarpa*). The talk was received by approximately 35 persons, each having interests in alternative crops.

A Maryland Cooperative Extension Twilight Tour was offered at the end of October 2007 which showed the wireless sensor network system in operation, utilizing the calibration data generated by this research.

In March of 2008, University Extension of Talbot County extended an invitation for a 4 hour workshop on alternative crops (see Appendix B for syllabus). In September of 2008 a field day at Raemelton Farm, an in-ground tree nursery in Adamstown, MD featured the remote wireless irrigation management system research funded in part by this Agro-Ecology Grant. The program was entitled "Staying Profitable Through Sustainable Field Nursery Production Practices" Over 40 growers, industry officials, State and Federal agency employees attended.

Additionally, 2009 extension programming containing information on this research included the annual "Sustainable Nursery Production" workshop in February again featuring the remote wireless irrigation management and future research plans. In all approximately 150 growers and both local and federal government agencies have been enlightened by this research.

Sawmill Hollow Organic Farms, Missouri Valley, Iowa, *P. malanocarpa* is being utilized as a successful alternative crop. Sawmill Hollow Organic Farms hosted the 2009 Aronia Festival where an invited extension talk was given to showcase the University of Maryland's research in both post-propagation production and in-ground production of *P. malanocarpa*. This talk was given to over 150 farmers from Iowa, Nebraska, Illinois, and Oklahoma. In August of 2010, another program hosted at the Wye Research and Education Center introduced Aronia to 30 potential growers in Maryland.

Since programming began on *P. malanocarpa* (Aronia), six farms in Maryland have received plants from this extension program and will be growing this crop for fruit production in spring of 2010. Over 550 plants have been distributed thus far to the following farms:

Al and May Pong
Pong's Orchard
12305 Carol Drive
Fulton, MD 20759.

Richard Uva
Seaberry Farm, LLC
2770 Wright Rd.
Federalsburg, MD 21632

Stephen and Lynda Blades
Blades Orchard
4822 Preston Road
Federalsburg, MD 21632

Kenneth Staver
3121 Price Station Rd
Centreville, MD 21617

Stanton Gill
Falcon Ridge Farm, LLC
4496 Jennings Chapel Rd
Brookeville, MD 20833

Gerry Godfrey
Fair Spring Nursery
18150 Templeville Road
Marydel, MD 21649

In two years, these farms will be producing Aronia fruit. An active extension program will assist these farms with growing Aronia based on an active research program. Further funding for marketing this crop is being sought to develop this fruit as a low impact sustainable alternative crop for Maryland.

Appendix C lists the research publications developed from this study program, most of which was accompanied by a talk at a research conference.

Website

The alternative crop website has been developed and will be presently active. The original domain name was alternatives4MD but because of the effort needed to promote Aronia in Maryland, this website will now be fully dedicated to extension and research on *P. melanocarpa.* The new website will be named www.aronia4MD.umd.edu. This website will be one of the primary outreach methods utilized to inform interested parties in the Aronia production sustainability requirements. While available online, many fields are presently under construction. They will feature the present research on Aronia and will also including present advances in irrigation technology funded by this Agro-Ecology Inc. grant. Impacts of the website will be tracked through Google Analytics.

Budget

The expenditure budget for the funding of this project is outlined in Appendix A. The extension and research efforts that have been and will be derived from this study will be of great value to Maryland farms. Headlining this research is the information about *P. melanocarpa* and the extension program that is being developed around this crop. As was stated earlier, 6 Maryland farms have adopted this plant with more expected by next year based on a program evaluation survey given at a recent University of Maryland Extension Program about Aronia. Because of the increasing popularity of this fruit sold by farms like Sawmill Hollow Organic Farms, this could be a value added product with a value similar or better than blueberries. This grant and research will be used as leverage for further funding, especially for increasing the market potential of this crop in Maryland.

Very important are the additional leveraged funds from this research study which include over $70,000 in other institutional grants for this research. Recently the data and information retrieved from the past 3 years of this research was instrumental in obtaining a $5.3 million grant though USDA/SCRI, acquired to further advance research on the wireless irrigation monitoring and control systems

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Appendix A: Budget

Table 1. First Year Budget Expenditures

YEAR 1 **ANNUAL BUDGETS: AS OF 7/07**

Budget Item and Description	MCAE Requested Amount	Spent from Requested	Balance of Requested
Salaries			
Student Technicians 932.75 hours @ $8.00 per hour	$ 7, 462	$ 6, 060	$ 1, 402
Subtotal Salaries and Benefits	**$ 7, 462**	**$ 6, 060**	**$ 1, 402**
Contractual Work			
Chesapeake Natives, Inc (propagation, research activities)	$ 18, 000	$ 18, 000	$ 0
Contractual	**$ 18, 000**	**$ 18, 000**	**$ 0**
Description of Equipment, Materials and Supplies			
Greenhouse Materials: Plants Containers Nutrients irrigation equipment (drippers, pvc pipes and fittings) greenhouse rent ($250 per month @ 10 months)	$ 2, 500	$ 2, 525	$ -25
Greenhouse Plant Analyses: (3 species x 3 trtmnts x 5 reps x 3 tissues x 4 harvests) = 540 samples @ $30 per sample for CNP analysis (1 species x 3 trtmnts x 5 reps x 3 tissues x 6 harvests) 270 samples @ $30 per sample for CNP analysis	$ 24, 300	$ 24, 300*	$ 0
Moisture Sensor Technology – Echo Probes 25 @$100 each Irrigation controller and extra probes	$ 2, 500	$ 1, 461	$ 1, 039
Web Site/Database Startup Funds	$ 2, 000	$ 2, 000	$ 0
Subtotal Equipment, Analysis and Supplies	**$ 31, 300**	**$ 12, 540**	**$ 18, 760**
Travel			
Travel - In-state Mileage between UMCP and WREC, UMCP Travel 115 miles @ $0.44 per mile 20x Out of state research Conf's **(SNA AND/OR ASHS)**	$ 1, 000 $ 1, 000	$ 502 $ 0	$ 1, 498
SUBTOTAL TRAVEL	**$ 2, 000**	**$ 502**	**$ 1, 498**
TOTAL YEAR 1:	**$ 58, 762**	**$ 37, 102**	**$ 21, 660**

*Transferred to last year

Table 2. Second and third year Budget Expenditures

YEAR 2 AND 3 (EXTENSION) **ANNUAL BUDGETS: AS OF 12/08**

Budget Item and Description	MCAE Requested Amount	Spent from Requested	Balance of Requested
Salaries			
Student Technicians 932.63 hours @ $8.00 per hour	$ 7, 461	$ 4, 000	$ 3, 461
Subtotal Salaries and Benefits	**$ 7, 461**	**$ 4, 000**	**$ 3, 461**
Contractual Work			
Chesapeake Natives, Inc (propagation, research activities)	$ 18, 000	$ 18, 000	$ 0
Contractual for years 2 and 3	**$ 18, 000**	**$ 18, 000**	**$ 0**
Description of Equipment, Materials and Supplies			
Ongoing Greenhouse Experimentation: Rent (250 per month@4 months		$ 0	$ 0
Ongoing Greenhouse Experimentation: Consumable's	$ 750	$ 750	$ 0
Greenhouse Plant Analyses: (3 species x 3 trtmnts x 5 reps x 3 tissues x 4 harvests) = 540 samples @ $30 per sample for CNP analysis (1 species x 3 trtmnts x 5 reps x 3 tissues x 6 harvests) 270 samples @ $30 per sample for CNP analysis	$ 24, 300	$ 0	$ 24, 300
CMU Site Development: Irrigation and electric (pipes, valves, solenoids, wires) Transfer boxes (25 @ $50) Sump Pumps (25 @ $50) Flow meters	$ 2, 500 $ 1, 000 $ 1, 250 $ 1, 250	$ 2, 500 $ 1, 000 $ 1, 250 $ 1, 250	$ 0
Field Site Development: Maintenance costs	-	$ 0	$ 0
Irrigation Research: Incidentals	-	$ 0	$ 0
Leachate Analyses: Platforms (24 x 40 weekly leachate samples) = 960@ $15 per sample	$ 14, 400	$ 0	$ 14, 400
Subtotal Equipment, Analysis and Supplies	**$ 45, 450**	**$ 6,000**	**$ 38,700**
Travel			

Travel - In-state Mileage between UMCP and WREC, UMCP Travel 115 miles @ $0.44 per mile 20x Out of state research Conf's **(SNA AND ASHS)**	$ 1, 000 $ 1, 000	$ 1,000 $ 1,000	$ 0
SUBTOTAL TRAVEL	**$ 2, 000**	**$ 2,000**	**$ 0**
TOTAL YEAR 2	**$ 72, 911**	**$ 30,750**	**$ 42, 161**
YEAR 1 CARRYOVER	**$ 21, 660**		**$ 21, 660**
GRAND TOTAL	**$ 94, 571**	**$ 30,750**	**$ 63, 821**

YEAR 4 **ESTIMATED ANNUAL BUDGETS: AS OF 12/08**

Budget Item and Description	MCAE Requested Amount	Spent from Carryover	Balance of Carryover
Salaries			
Student Technicians 932.63 hours @ $8.00 per hour	$ 0	$ 3, 461	$ 0
Subtotal Salaries and Benefits	**$ 0**	**$ 3, 461**	**$ 0**
Contractual Work			
Chesapeake Natives, Inc (research activities)	$ 0	$ 7, 500	**$ 0**
Contractual	**$ 0**	**$ 7, 500**	**$ 0**
Greenhouse Plant Analyses: (6 species x 3 trtmnts x 5 reps x 3 tissues x 3 harvests) = 810 samples @ $30 per sample for CNP analysis	$ 0	$ 24, 300	
Leachate Analyses: Platforms (24 x 40 weekly leachate samples) = 960@ $15 per sample	$ 0	$ 14, 400	$ 0
Contractual		**$ 38, 700**	**$ 0**
***CMU Site Development**: **Flow meters** **G2 commercial 8 @ $354** **AI industrial 4 @ $526** **Flow meter repair 4 @ $250 each** **Flow meter batteries 100 @ $10 each** **Node Batteries 2 cases @ $52 each** **Decagon Wireless Nodes 2 @ $675** **Additional Moisture Sensors 40 @ $75**		$ 2, 104 $ 2, 832 $ 1, 100 $ 1,000 $ 104 $ 1, 350 $ 3, 000	$ 4
Total		**$ 11,490**	$ 0
Equipment Replacement and Repair			
Plant Tissue Mill Repair		$ 1, 550	
Total		**$ 1, 550**	
Travel			
Travel - In-state Mileage between UMCP and WREC, UMCP Travel 115 miles @ $0.44 per mile 10x	$ 0	$ 1, 000	$ 0
TOTAL YEAR 4	**$ 0**		**$ 0**
YEAR 2 CARRYOVER	**$ 63, 821**	**63,701**	**$ 63, 821**
GRAND TOTAL (FROM ALL BUDGETED YEARS)	**$ 139, 673**		**$ 120**

*year end extra funds transferred to equipment improvement, replacement and repair

Appendix B: Example of Alternative Crop Programming: A Syllabus

Talbot Small Farm Training
Alternative Crops
Andrew Ristvey
Saturday, March 8, 2008

1. The Green Industry in Maryland
    - Economic Value of the Green Industry in Maryland
    - What comprises the Green industry?
        - Greenhouse
        - Container Production
        - Field Production
            - Soil
            - Pot in Pot – a hybrid
            - Landscaping etc.
    - What interests you?
    - What is your market?

http://bluestem.hort.purdue.edu/plant/FMPro?-DB=plant.fp3&-Format=category.html&-Max=100&-SortField=Description&category=Getting%20Started&-Find
http://hbin.tamu.edu/

2. Licensing and Certifications. Online information
    - Local Permits
    - Maryland Department of Agriculture
    - Maryland Department of the Environment
        - http://www.mda.state.md.us/licenses_permits/
        - http://www.blis.state.md.us/

3. University of Maryland Cooperative Extension- What we can do for you!
    - Programming and Training
        - Nutrient Management Certification
        - Pesticide Certification
        - "How to" Programming
    - Fact Sheets
        - Starting a Greenhouse - http://extension.umd.edu/publications/PDFs/FS593.pdf
        - Starting a Nursery - http://extension.umd.edu/publications/PDFs/FS660.pdf
        - Staring a Tree Farm - http://extension.umd.edu/publications/PDFs/FS661.pdf
    - Web Sites
        - http://www.grapesandfruit.umd.edu/
        - http://www.smallfarmsuccess.info/index.cfm

4. The Greenhouse Business Economics
    - Ben Beale – St. Mary's County Extension Educator

5. Alternative Crops for Maryland: Beach Plum and Black Chokeberry, Potential for Organic Production
   Andrew Ristvey and Ben Beale

6. Some Success Stories
   Priapi Gardens - http://www.priapigardens.com/
   Emroy Knoll Farms - http://www.greenroofplants.com/
   Lohmeyer Farms - http://home.dmv.com/~kcl/ghheat2/
   Flowers by Bauers - http://www.flowersbybauers.com/aboutus.html

Appendix C: Publications from this Research

Arguedas, F.R., J. D Lea-Cox and A.G. Ristvey, 2007. Characterizing Air and Water Content of Soilless Substrates to Optimize Root Growth. Comb. Proc. Int. Pl. Prop. Soc. Vol. 57:103-110

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Lea-Cox, J.D., A.G. Ristvey, F. Arguedas Rodriguez, D.S. Ross, J. Anhalt, and G. Kantor. 2008b. A low-cost multihop wireless sensor network, enabling real-time management of environmental data for the greenhouse and nursery industry. Acta Hort. (ISHS) 801:523-530

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