COOPERATIVE DEVELOPMENT INSTITUTE

The Northeast Center for Cooperative Business

PROJECT # 10–12: Converting Dairy Manure Fiber into Plant Growing Media as a Nutrient Removal Strategy

FINAL 319 REPORT

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REPORT DATE: SEPTEMBER 28, 2015

PROJECT # 10-12

CONVERTING DAIRY MANURE FIBER INTO PLANT GROWING MEDIA AS A NUTRIENT REMOVAL STRATEGY

Project Summary

Determine the viability of using dairy manure fiber, a by product of anaerobic digestion, in growing media for commercial plant production. Fibers and associated nutrients would be removed from dairy farms and used by plant growers as a sustainable alternative to peat in potting mixes, thus reducing non-point source nutrients from farmland watersheds. Building on research done at Washington State University, trials using digestate fiber based potting mixes to grow annuals, perennials and woody plants will be conducted at commercial greenhouse and nursery sites under the supervision of the University of Connecticut. Digestate dairy fibers from different farms will tested periodically to assess variation in nutrient, pathogen, weeds and pH characteristics.

Project Objectives

1. Develop potting mix 'recipes' for various plants using dairy manure fibers, plan trial protocols, speak with farmers and advisory committee and provide a summary of potting mix 'recipes' for various plants using dairy manure fibers, a summary of plant trial protocols and activities with farmers and advisory committee members including any supporting documentation.

2. Organize, supervise, collect and analyze data from 7 plant trials at three sites with annuals, perennials and woody plants; develop QAPP.

3. Organize, collect and test digestate fiber from dairy farms.

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LIST OF ABBREVIATIONS

ADDF	anaerobically digested diary fiber
BARK	aged or composted pine bark
CCAP	water retention at container capacity
COIR	coconut fiber extraction residuals
GDF	ADDF:peat: perlite mix used at Grower Direct Farm
GD2	standard peat: perlite used at Grower Direct Farm
PBRH	parboiled rice hulls
PEAT	sphagnum peat
PERL	perlite
PT	pourthru extract(ion)
SME	saturated media extract(ion)
SPM	soilless potting mix(es)

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Executive Summary

The objective of this project was to evaluate the use of anaerobically digested dairy fiber (ADDF) a by-product of methane extraction from dairy manure, as a renewable alternative for sphagnum peat in a wide variety potting mixes for both greenhouse and nursery crops.

A diverse selection of 18 greenhouse and nursery crops were grown in 9 potting mixes with and without ADDF, in two commercial and one research greenhouse, and evaluated for growth, quality and nutrient uptake. Mixes with ADDF as a partial or complete replacement for peat produced plants of equal or greater size and quality to those grown in a standard peat-based mix for most crops. All plants grown in ADDF-containing media had greater tissue phosphorus concentrations than those grown in peat-based mixes.

The project supported research into growing woody or herbaceous perennials in ADDF mixes. The robust nature of woody perennials makes them excellent choices for test subjects to grow in ADDF. The longer growing season of nursery crops presented an opportunity to further investigate the physical properties of ADDF over time, particularly shrinkage.

The results of physical and chemical evaluation of ADDF potting mixes support the conclusion that ADDF can substitute effectively for peat in potting mixes, and that nutrients in ADDF can help meet fertilizer requirements. Plant growth trials support the potential for using ADDF as a peat substitute. Further research is required to determine if greenhouse and nursery irrigation and fertilization management practices could be modified to improve results with species that did not do as well in ADDF potting mixes. Skilled attention to chemical properties of ADDF mixes is required, which may present a challenge for plant management.

Introduction

This project is Phase 3 of an effort to help dairy farmers develop options to remove excess nutrients from manure, in order to meet the Connecticut Department of Environmental Protection's (DEP) non-point source pollution goals.

The Woodstock Nutrient Management Feasibility Study produced by Wright-Pierce in Phase 1 (July 2007) identified anaerobic digesters and aerobic compost options for converting surplus manure into energy producing and bio-available products. Phase 1 revealed that while an anaerobic complete mix digester was modestly profitable on the largest farm, none of the aerobic composting options were financially feasible.

Phase 2 (September 2009) conducted by the Cooperative Development Institute confirmed Phase 1 findings and presented a business proposal for an anaerobic digester system that maximized revenues from gas and effluent and reduced the potential for non-point source pollution from nutrients generated by farming operations while being compatible with and supportive of the core dairy farm business operations and finances. Phase 2 concluded that the profitability of a digester is dependent on choosing an appropriate and well-engineered design, careful management of equipment, labor and other inputs that is integrated into the farm's operations, and the sale and use of four by-products: gas, electricity, fibers and fertilizer. To enhance the environmental sustainability of two of CT's main agricultural industries, and to improve digester economics, Phase 3 was recommended: applied research to determine whether ADDF was feasible as a substitute for peat by CT's horticultural industry.

Peat-based plant growing media is the industry standard. Potting mixes for greenhouse production typically contain 60% to 80% peat by volume. Peat is becoming increasingly expensive and less available due to peat bog destruction and environmental protection laws. Growing consumer awareness and interest in green, sustainable horticulture practices has created an opportunity for alternatives. Phase 3 explored whether ADDF could be that alternative.

Anaerobic digestion (AD) is a biological process in which unstable, biodegradable organic materials are broken down by bacteria in an oxygen-free environment. AD speeds up and contains the process of manure decomposition, producing gas and a stable, nutrient rich slurry. The slurry can be separated into w fertilizer and moist, fluffy, peat-like solids, ADDF, which are nutrient rich, odor-free, pathogen-free with significantly reduced weed seeds.

Similar to compost produced by aerobic decomposition and like peat, ADDF is a stable product, and is not prone to further decomposition. An aging study conducted as part of work to determine potential for use in potting mixes, confirmed that the storage does not degrade the fiber or adversely affect its use as a plant growing medium (MacConnell 2006). Because of the highly controlled nature of the anaerobic decomposition process in the digester, if consistency in feedstock is maintained (as on a dairy farm vs. a commercial waste operation) the fibers will maintain consistency as a finished product for nutrient levels, weeds, pathogens, etc. ADDF have the same physical characteristics as peat, including bulk density, water retention and porosity, to support root development with sufficient space for water and air and to retain moisture. (MacConnell 2006, Oakley 2006, Zauche and Compton 2005, Zauche 2006)

ADDF differs from peat in several important ways. Fibers are alkaline with a pH of 8.5 to 7.5 and fibers contain nutrients that can be taken up by plants; peat on the other hand is very acidic with a pH of 3.6 to 4.2 and is not a significant source of nutrients. Thus ADDF cannot be directly substituted for peat, but rather need to be acidified according to the specific needs of the plant being grown.

When separated from the digestate slurry, ADDF is typically 60% moisture. Peat is typically 40% moisture. Drying the fibers does not adversely affect the material. Because nutrients are water soluble, ADDF must be stored undercover to protect against rain, snow and other sources of water which might unbalance the nutrient distribution.

ADDF has higher electro-conductivity (salts) than peat due to the presence of nutrients; trials have not shown that trait to be problematic for nutrient uptake by plants. Fertilizer savings may be obtained over peat-based mixes, which require the addition of fertilizer to compensate for the substrate's lack of nutrients.

When compared to dairy compost, fibers have better buffering capacity to maintain the pH of a potting mix and, most important, greater porosity (Zauche 2006 and MacConnell 2006). Since fibers and compost values derive from the specifics of the originating manure, quantification of typical comparative values show ranges. Fibers and compost have similar NKP values, e.g. fiber N= 1-2% vs. 1-3% for compost, fiber K = 1.6 vs. compost about 0.2 - 3%, fiber P: 0.2-1% vs. compost P 0.2-1%, and thus lower conductivity than compost. The two materials have comparable pH values (fiber 8.5, compost 8.4), C/N (fiber: 20-40, compost 11-20) and conductivity (fiber 9.9, compost 11). (Alexander 2008, Zauche 2006, MacConnell 2006, Cornell 2004, DeBruyn 2008).

Research conducted independently at the University of Washington (MacConnell) and the University of Wisconsin-Platteville (Zauche and Compton), resulted in 'recipes' or formulas which adjust the chemical composition of fiber for use in soilless potting mixes. These recipes are proprietary and have been submitted for patent approval. Published research from these trials and consultation with one of the leading researchers provided baseline information from which to develop the 'recipes' used in Phase 3 trials.

Phytotoxicity (toxins in the material which harm plants) is a major concern of plant growers and is the principal reason for their limited use of compost (and thus a barrier to ADDF adoption). Variability of compost is due inconsistent feedstocks and management. Testing procedures are often inadequate for use in high-value applications. Issues with compost include residues of the herbicides such as clopyralid, heavy metal content, soluble salts, organic acids and oxygen deprivation resulting from incomplete decomposition of the source material. (Blewett et al. 2005)

Organix, Inc. was the first company to commercialize ADDF as a peat replacement. Their claims for RePeat:

In addition to looking, feeling and smelling like peat; RePeat™ is more pH neutral than peat moss (6.5 vs. 4.5); RePeat™ has low salt content and as a result has low electrical conductivity; RePeat™ has excellent porosity and water holding capacity like peat; Cationic exchange ability is comparable to mined peat and Bulk density (weight) of RePeat™ soil amendment is very similar to that of peat. These characteristics are also claimed in work done by Zauche and Compton at the University of Wisconsin at Platteville.

They found that ADDF solids:

- Contain more humic acid than compost and within 30% of peat
- Need to be mixed with other materials for optimal plant growth
- In mixes produce plants with 30 to 40% more growth than peat
- Are better at maintaining pH than compost due to a high buffering capacity

Because plant needs for moisture, nutrients and aeration vary by type, so too must potting soil 'recipes' made from digester solids (or peat) vary. MacConnell, Zauche and Compton have developed recipes for geranium, petunia, phlox, begonia and impatiens as well as for orchids (lady slippers).

Patent pending recipes include perlite, vermiculite and other amendments in mixes. Their economic analysis suggests that solids based potting mixes would cost about 20% less than peat based mixes. Other savings to growers may be obtained from reductions in fertilizer and better growth yields that can bring plants to market sooner.

As with dairy farmers, plant growers are extremely cautious when it comes to the adoption of a new technology or as in this case, a new potting mix. Not only is there concern about performance (despite published research findings), but also about changes that would have to made in plant management systems, for example water and fertilizer. Plant growers would have to try the recipes in their operation to see firsthand how the mixes worked before they would consider making a change. Plant growers need to be convinced of product worthiness and to assess management impacts (labor, fertilizer, water). Thus Phase 3 was designed to interest at least one grower in a pilot study—growth trials using AD solids recipes for various bedding and perennial plants. Principal Investigator Dr. George Elliot, Associate Professor of Horticulture, University of Connecticut who has worked with CT horticultural industry, with the Freund Farm ADDF cow-pot project and who had been doing research in the substrate field added a wealth of expertise and credibility to the study.

SUMMARY

Developing alternative uses of ADDF would contribute to the economic feasibility of anaerobic digesters as a technology that helps farmers reduce opportunity for non-point nutrient discharge from raw manure into farmland watersheds.

Diverting nutrients in ADDF from farmland to commercial plant production would reduce fertilizer requirements for plant growers and provide a potting alternative that would address concerns over the environmental impact and sustainability of continued peat use in greenhouse mixes, up to 80% or more of the total mix volume. Replacing all or part of the peat used in potting mixes with ADDF represents great potential to significantly reduce demand for peat and the associated diminished ability of mined peat bogs to sequester carbon and regulate water movement and quality as well as to reduce the energy and emissions costs of shipping peat from far northern regions.

The Resource and Environmental Problem

The potential impact of dairy manure as a non-point source of watershed pollution is the impetus for dairy farmers to adopt anaerobic digestion to process manure.

If manure is not stored and processed properly it can release significant amounts of nitrogen, phosphorus and methane, a greenhouse gas almost 25 times as powerful as carbon dioxide, into the environment. Unprocessed dairy manure is typically spread on crop fields in the spring to maximize nutrient availability to crops. While amending crop fields with manure improves soil structure and recycles some nutrients from the manure into the crop, much of the nutrition can be lost in the form of runoff. When manure is applied to the same fields year after year nutrients, especially phosphorus, can accumulate excessively and slowly leach out, polluting water resources.

Anaerobic digestion is an alternative way to process manure in which manure is fermented in an oxygen-free environment. Anaerobic digestion allows farmers to reduce odors and collect the methane produced by the fermentation process for use as a biofuel. After anaerobic digestion is complete, the solid and liquid fractions are separated; the solid fraction is ADDF. Anaerobic digester systems can be used to reduce odor, stabilize and contain manure as well as capture methane for use as a biogas fuel. Methane can be sold or used for onsite energy production. Currently, the fibrous solids left over after digestion is complete (ADDF) are usually used for animal bedding and spread on crop fields as is done with raw manure. Finding a more lucrative use for ADDF would generate new revenue for dairy farmers and incentivize the adoption of anaerobic digester systems.

Peat based potting mixes have been an industry standard since the introduction of Cornell University's "peat-lite" mix in the 1960s. Today concerns over the environmental impacts of harvest and shipping have led many to question its sustainability. Peat has a distribution of large and small pores that gives it excellent water holding capacity and aeration, ideal for the growth of plant roots. Peat is also easily adaptable to a wide variety of growing practices, media blends and crops. Peat owes much of its desirable attributes to the way it is formed; under anaerobic conditions in peat bogs. These conditions preserve the fibrous cellulose structure of the plants the peat is formed from.

Peat is mined from peat bogs which serve a variety of ecological functions including carbon sequestration and regulating water movement and quality. Harvesting peat from deep in the bogs can quickly remove hundreds of years of peat accumulation and release significant amounts of carbon into the atmosphere. This drastically alters the chemical, physical and biological composition of peat bogs. Peat is harvested by cutting strips from peat bog up to 1 meter deep. Peat only reforms at a rate of 1-2 mm per year so each harvest represents hundreds of years of peat formation. While efforts to restore peat bogs after harvest are commendable, it is questionable whether ecological functionality can ever be completely restored or whether peat is a truly renewable resource. Most peat is produced in cold, northern regions and must be shipped long distances to more temperate horticultural areas contributing further to fossil fuel consumption and carbon emissions. All of these environmental concerns have fostered a search for more sustainable alternatives to peat in potting media.

SUMMARY

The greenhouse, nursery and dairy industries are important to the New England economy and generate about one third of all agricultural cash receipts in New England (New England Agricultural Statistics, 2012). The environmental horticulture industry of New England represents almost 5 billion dollars, 11,900 firms, and 156,000 jobs and is growing. Nursery production represents a significant portion of this industry with almost half of New England horticultural firms engaged in some kind of production enterprise (New England Nursery Association, 2009). The dairy industry of New England has historically been, and continues to be a vitally important part of the region's economy contributing over 3 billion dollars to the region's economy annually. ADDF shows promise as a locally sourced, inexpensive, sustainable alternative to peat for growers in the Northeast.

The Solutions

Marketing ADDF as a useful horticultural material, in conjunction with methane production, can provide another source of income for dairy farmers and provide a solution to the waste management problems associated with raw manure.

Methane extraction from manure shows great promise, but revenue generated by energy production alone is often not enough to offset the costs of constructing and operating anaerobic digesters. If ADDF were proven as a high quality media component, it would be a value-added product to augment dairy costs. The demand for ADDF from growers would be an added incentive for dairy farmers to adopt the more sustainable anaerobic manure digestion systems. Additionally, if ADDF were used in a growing media, nutrients that would otherwise be lost as pollutants would be used for plant nutrition.

Greenhouse mixes typically contain a large proportion of peat, up to 80% or more of the total mix volume. Replacing all or part of it could represent a great potential to significantly reduce demand for peat. While nursery mixes usually contain a smaller proportion of peat than greenhouse mixes, nursery crops are generally grown in larger pots and require a larger volume of media so a smaller proportion of peat in a larger volume of media still accounts for a significant amount of peat consumed.

Peat and ADDF have many similarities in how they are formed and in their physical properties. Both materials are formed under anaerobic conditions in which they are fermented by similar microbes. Anaerobic digesters have even been referred to as "short term, renewable peat bogs". An analysis of physical properties showed that peat and ADDF have similar water holding capacity, porosity and bulk density. There are, however, some important differences between the chemistry of peat and ADDF. Peat is quite acidic with a pH less than 5, whereas ADDF is somewhat alkaline, with a pH greater than 7.5. ADDF also contains significant quantities of soluble nutrients, especially phosphorus. However, it also contains higher concentrations of total soluble salts than peat. In the growth trials at UConn, the availability of these nutrients to plants was evaluated to determine if additional nutrition provided by ADDF could reduce fertilizer inputs.

ADDF RECIPES

ADDF can be used as a partial or complete substitute for peat in combination with other bulk components such as composted bark, coir, perlite and parboiled rice hulls. Following are two recipes for ADDF potting mixes that have been used in greenhouse and nursery production, respectively:

- **40% PEAT: 40% ADDF: 20% PERLITE**
  - Add gypsum at about 2.5 lbs/yd3 (4 kg/m3)
- **50% BARK: 33% ADDF: 17% SAND or PERLITE**
  - Add gypsum at about 2.5 lbs/yd3 (4 kg/m3)
  - Sand for outdoor production in large pots where a higher bulk density is desirable; perlite for small pots and protected cultivation

Methods and Results

Following a review of the dairy fiber as peat substitute literature and consultation with the Project Researcher from Washington State University (WSU), Craig MacConnell, two basic criteria for dairy fiber were developed:

1) Determine use of copper sulfate if any in animal foot baths. Fiber that is free of or with very low levels of copper sulfate is appropriate.
2) Determine storage conditions. Dairy fibers that are stored on a slab and under cover are appropriate.

Following site visits and a preliminary assessment of fiber suitability, an appropriate farm was identified, Freund Farm, East Canaan, CT. The farm's involvement and ADDF were obtained. The Principal Investigator, Dr. George Elliott, UConn collected a sample and sent the material for testing according to WSU protocols. The fibers tested lower in pH and salts than fibers in west coast studies. While a positive finding, it meant that the 'recipes' developed in the WSU trials could not be exactly replicated as planned. Recipes were adjusted to meet substrate suitability for plant growth.

Blending, incubation and testing of ADDF integrated potting mixes was conducted at UConn to make sure the substrate was appropriate for the greenhouse and nursery trials. The trial potting mix for the first trials was sampled and tested for pH, EC and soluble macronutrients at intervals for 2 weeks. Adjustments were made and blended, incubated, tested and sampled. Potting mixes contained ADDF, peat or coir, and perlite or parboiled rice hulls.

Growing trials for selected herbaceous and woody plants were conducted at three locations: two commercial growers and at the University of Connecticut Floriculture Greenhouse. In most trials, plant growth in potting mixes containing ADDF was compared with commercial potting mixes. Potting mixes were extracted during crop production to evaluate nutrient availability. Plant tissue was analyzed to evaluate nutrient uptake.

A. PHYSICAL AND CHEMICAL PROPERTIES OF ADDF AND POTTING MIXES

ADDF was obtained from Freund Farm, East Canaan, CT in November 2011, May 2012 and January 2013. The material was taken from static piles stored on a concrete floor in a storage barn. The samples taken in 2011 and 2013 were hand collected from random locations near the surface of the pile after scraping away the outer layer. Material was warm and somewhat odorous. In 2012 larger quantities were collected with a backhoe and shipped in bulk bags to UConn and Grower Direct Farm, Somers, CT. The material was sampled as received from the farm.

Samples from the November 2011 batch were analyzed by the Soil and Plant Laboratory, Inc. This lab uses proprietary versions of standard methods to evaluate physical and chemical properties of soils and growing media. Physical properties were evaluated in 4 inch and 6 inch columns (Tables 1 – 2). Parameters included container capacity (CCAP; volumetric water retention after saturation and free drainage), bulk density, water retention and aeration at tensions up to 50 centibars. Differences between the 4- and 6-inch columns were negligible. CCAP was about 66% and aeration at CCAP about 20%, amounting to a total porosity of 86%. Readily available water, calculated as the difference between CCAP 50 centibars tension, was about 35%. Bulk density reported in lbs./cu.ft. was 60 for saturated material, 47.5 at CCAP and 6.7 when dry.

Electrical conductivity (EC) in a saturation extract was 1.9 dS/m, considered tolerable for crops (Table 3). However, the concentration of Sodium was 10.8 meq/L, which might restrict the use of ADDF for salt-sensitive crops. The pH was 7.4, a level taken to indicate slight alkalinity. Available Nitrogen was considered very low, and dominated by Ammonium. Potassium concentration was very high, while Calcium was very low and Magnesium optimum, with a Ca: Mg ration of about 1:1. Zinc concentration was very high and Iron was low, but other micronutrients were in the optimum range.

Samples from the May 2012 batch were analyzed by the JR Peters Laboratory. Physical properties were evaluated using the NCSU porometer (Table 4). The results for CCAP were similar to the previous test at about 65%, but the porometer method indicated substantially less air space at 7%. The dry bulk density was similar at about 7.3 lbs./cu.ft.

Chemical characteristics were evaluated in saturated media extracts (SME). Values were qualitatively similar to those obtained with the previous samples (Table 5). However, the EC was higher than the normal range at 3.78 dS/m, while Zn and Fe concentrations were within the normal range.

Due to uncertainty regarding funding for analytical services at the time, material collected for trials in 2013 was not analyzed as extensively as the previous samples. However, samples of new material as well as material remaining from the 2012 batch were dry-ashed and sent to the UConn Soil Nutrient Analysis Laboratory and tested for total content of macro- and micronutrients (Table 6). Results indicated that the differences between batches were negligible. Concentrations of P, K, Ca and Mg on a dry weight basis were higher in the old material, probably as the result of microbial respiration and loss of C during storage.

Physical and chemical properties of ADDF were determined unsuitable for use as a sole component potting medium. In particular, high pH and EC indicated that ADDF would have to be blended with other materials for use in potting mixes. Mixes containing ADDF blended with sphagnum moss peat (PEAT) or coconut fiber processing residuals (COIR) and perlite (PERL) or parboiled rice hulls (PBRH) were evaluated. Peat and coir were used as bulk components in equal proportions to ADDF. Peat is strongly acidic and has low EC so could counter the alkalinity and high EC of ADDF. PERL and PBRH were used to improve drainage and aeration. The first mix evaluated was a blend of 40% ADDF, 40% peat and 20% PERL amended with gypsum at 1.2 kg/cu. m. This mix (GDF) was used for garden mum production as a substitute for the standard mix used at Grower Direct Farm (GD2), which contains 80% peat and 20% perlite plus lime and gypsum. GDF had physical properties similar to GD2 (Table 7). Although total porosity and CCAP were slightly lower in GDF than GD2, aeration was slightly higher. As expected, GDF pH and EC were lower than ADDF (Table 5). Addition of gypsum increased Ca and S concentrations in SME. Concentration of P increased in GDF compared to ADDF, possibly the result of neutralizing alkalinity, which could decrease P solubility.

ADDF was stored on site approximately 2 months prior to use in trials in 2012. During this period the pH evidently decreased as a result of nitrification. The GDF mix prepared for trials had lower pH and higher NO3-N but lower NH4-N and P concentration than the preliminary test mix (Table 8). A preliminary trial was conducted with a mix of 40% ADDF: 40% COIR: 20% PERL (DCF). The pH of coir is near neutral, and the mix therefore had much higher pH.

Four potting media containing ADDF were evaluated in 2013. All mixes contained 40% ADDF. Two mixes were blended with 40% PEAT and 2 with 40% COIR. Two mixes contained 20% PERL and 2 contained 20% PBRH. These mixes were compared with a commercial potting mix containing approximately 80% PEAT: 20% PERL. In trials conducted in spring 2013, only the peat mixes were evaluated. Preplant SME results were similar to previous trials (Table 9). In trials conducted in summer and fall 2013, both peat and coir mixes were evaluated. COIR mixes had significantly lower CCAP but greater aeration than PEAT mixes (Table 10). PBRH increased porosity compared to PERL. The pH of ADDF: PEAT mixes used in these trials was somewhat higher than previously observed.

A trial to evaluate the use of elemental sulfur (S) to neutralize alkalinity in ADDF mixes. was conducted. Samples were incubated 3 weeks at 20 C and subsamples were taken for pH measurement during the incubation period. pH equilibrated within about 2 weeks of incubation (Table 11). Addition of S decreased pH, but the effect of increasing S was not consistent. pH decreased more in PEAT mixes than COIR.

B. CROP PRODUCTION TRIALS

Trial 1

Grower Direct Farm (GDF) and University of Connecticut Floriculture Greenhouse (UConn), garden mum trial, summer 2012.

Potting mix containing 40% ADDF: 40% PEAT: 20% PERL was prepared at Grower Direct Farm (GDF) on July 18, 2012 using an auger mixer and used immediately to fill 8-inch pots. Garden mum liners propagated at the farm and left over from their scheduled plantings were transplanted by hand and moved immediately to an outdoor field. Pots were irrigated using drip tape. After initial irrigation with water, pots were fertilized at every irrigation with a 18-3-18 fertilizer solution at 100 mg N/L. A 20-10-20 fertilizer at 200 mg N/L was applied on August 24. Flowable lime was applied once during the week of July 31. Pour-thru (PT) extracts were collected on August 14 and 29. SME samples were collected from pots August 21. Median mature leaves were collected on August 29 for nutrient analysis. Six pots of GDF mix were relocated to the University of Connecticut Floriculture Greenhouse (UConn) for a trial comparing the GDF mix with DCF mix prepared at UConn. PT extracts were collected one week after planting for both GDF and DCF mixes. Flowable lime was applied twice to GDF mix following the initial PT extract. A second PT extract was collected after the flowable lime applications. Plant growth was evaluated visually and photographs were taken to document crop appearance on August 7, 22 and 29 and October 26.

SME of GDF mix collected by the grower 1 week after planting indicated pH was low but within normal range (Table 12). PT extracts collected following the flowable lime application indicated pH remained within normal range. EC values were low until after the 20-10-20 fertilizer application. Phosphorus concentration decreased to 4.3 mg/L, below the normal range, but increased to the normal range following the 20-10-20 application. Leaf tissue nutrient analysis indicated that all nutrients except Zn were within normal limits.

Although the crop was planted late and the liners were past their prime, they established quickly and developed normally. On August 3 the grower reported "The crop looks good, good foliage color and the roots are developing normally". A photograph taken on August 7 (Figure 1) shows that the plants in GDF mix (on the right in the photo) appear healthy. By August 29 (Figure 2) the plants had filled out, and by mid-October (Figure 3) had matured to produce a commercially acceptable crop.

In the parallel trial at UConn, a rapid decrease in pH in the GDF mix was notices but not the DCF mix with coir (Table 8). A PT extract taken 1 week after planting had a pH of 4.49, well below the normal range and at a level which could cause problems with excessive micronutrient availability. Two applications of flowable lime corrected the problem.

Trial 2

Freund Farm, bedding plant trial, Spring 2013

A mix consisting of 40% ADDF: 40% PEAT: 20% PERL was prepared at UConn using ADDF collected at Freund farm in January 2013. The mix was delivered to the greenhouse at Freund Farm on March 20, 2013. The grower established a trial comparing ADDF mix with their standard growing mix, Fafard 1-P. The grower filled 4" CowPots® and planted a variety of spring annuals. Pots were irrigated by hand and fertilized with Plantex 19-2-19 at 100 mg N/L. The trial was evaluated visually on April 29. The plants growing in the two mixes were indistinguishable (Figures 4 -6). A few petunias showed signs of iron deficiency, probably due to alkalinity from ADDF (Figure 7). However, most appeared normal (Figure 8). The grower reported there were no problems with the ADDF mix.

Trial 3

UConn, bedding plant trial, Spring 2013

Two mixes using ADDF, PEAT and PERL or PBRH in the same proportions: 40% ADDF: 40% .SPM: 20% PERL or PBRH. Mixes were amended with gypsum at 4 kg / m^3. Sunshine mix #2 was used as a commercial control. Plants were potted in these mixes in 3.5 or 4" pots. Violas were potted in 3" Cowpots. Test plants were Pansy 'Karma White', Viola 'Penny Jump-up', Petunia 'Fusable Vogue', Geranium 'Pinto Dark Rose' (from seed) and Geranium 'Patriot Red' (from cuttings). Plants were grown on in greenhouse compartments with temperature set points appropriate for the species. Plants were irrigated using overhead hand watering initially, then in sub-irrigation trays. Constant liquid feed was provided with Plantex 19-2-19 at 100 mg N/L.

Photographs confirmed visual evaluations that pansies grown in both ADDF mixes were noticeably smaller and paler than those in the control (Figures 9-10). However, violas grown in the ADDF mixes in Cowpots were larger and more floriferous than the control (Figure 11). Petunias grown in the ADDF+PBRH mix were pale and smaller than those in ADDF+PERL, but both ADDF mixes produced larger plants than the control (Figure 12). Seed geraniums were drastically affected by potting mixes (Figure 13). Seedlings planted in the ADDF+PBRH mix were severely stunted and 19% of the plants were dead or moribund by the end of the trial. Plants in the control mix were not as stunted, but 44% were dead or moribund. Plants in the ADDF+PERL mix were somewhat pale, but larger than the controls and there was no mortality. Geranium cuttings grown in ADDF mixes were somewhat paler than the controls, but there was no apparent difference in size (Figure 14).

Shoot fresh weights were measured following harvest of mature plants from each crop. Plant tissue was then dried, ground and ashed for P analysis. Pansies in ADDF:PERL were not significantly different from the control, but plants in ADDF:PBRH were significantly smaller (Table 14). Violas grown in ADDF mixes were not significantly different from each other, but were almost twice as large as the controls. Petunias grown in ADDF:PERL were larger than those in ADDF:PBRH, which were larger than the controls. Geraniums from seed were significantly larger in the control mix than in ADDF mixes, but mix had no effect on geraniums from cuttings. Concentration of P in leaf tissue was significantly greater with ADDF mixes than the control.

Trial 4

UConn, garden mums trial, Summer 2013

A previous trial with garden mums at Grower Direct Farm during summer 2012 demonstrated that a commercially acceptable crop could be produced with a mixture of 40% ADDF: 40% PEAT: 20% PERL. However, that trial was limited to a single formulation and did not include a control. The 2013 trial at UConn was conducted to evaluate different ADDF mixes and compare them with a commercial control. The 4 formulations were 40% ADDF: 40% PEAT or COIR: 20% PERL or PBRH. ADDF mixes were amended with gypsum at 4 kg/m^3. Sunshine mix #2 (80% peat: 20% perlite) was used as a commercial control. Cuttings of garden mum 'Hanki Yellow' were transplanted in standard 8 inch mum pans on July 2. Plants were grown outdoors (Figure 15) using standard cultural practices. Pots were watered daily as needed using a precision drip irrigation system. Constant liquid feed was provided with Plantex 19-2-19 at 100 ppm N.

The plants grown in the control mix were noticeably larger than those in the ADDF mixes (Figure 16). Among the ADDF mixes, PEAT was superior to COIR, and PERL (DFPP and DFCP) was superior to PBRH (DFPR and DFCR). These observations were supported by size and fresh weight measurements (Table 15 I.). Plants grown in the ADDF mixes containing 20% PERL, though smaller than the control, were still commercially acceptable. Plants grown in mixes containing 20% PBH were too small and immature. Visual observation indicated that plants in COIR mixes were subject to water stress, suggesting that increased irrigation frequency might have improved plant growth. Since all the pots were irrigated on the same system, it was not possible to adjust irrigation frequency to each mix.

SME extracts showed that although the pH of all the mixes at midcrop was within the range 6.4 to 6.7, the pH of ADDF mixes increased while the pH of the control decreased (Table 15 II.). PT extracts inconsistent results, but COIR mixes tended to have lower concentrations of NH4-H and NO3-N than PEAT mixes or the control.

Trial 5

UConn, Cyclamen trial, Fall 2013

Two varieties of miniature cyclamen, Winfall White and Silverheart White, were planted on August 14 in 4 inch pots in freshly mixed batches of the same media as the garden mum trial. The ADDF mixes had elemental S incorporated at 3 kg/m^3 in addition to gypsum at 4 kg/m^3. The crop was grown using standard procedures. After initial overhead irrigation with water, pots were placed in sub-irrigation trays and supplied with 19-2-19 fertilizer at 100 mg N/L. Plant size was evaluated on November 20 by measuring the height and average width. Canopy volume was calculated as the product of height and width assuming a hemispherical shape. Plants grown in ADDF:PEAT mixes were not significantly different from the control, but plants grown in ADDF:COIR were smaller (Table 16 and Figure 17).

Trial 6

UConn, Poinsettia trial, Fall 2013

On August 23, 2013 poinsettia liners were transplanted into 6 inch jumbo azalea pots with the same potting mixes as the cyclamen trial. After initial irrigation with water, pots were placed in sub-irrigation trays and supplied with 19-2-19 fertilizer at 100 mg N/L. A strong sulfur odor was noted in the ADDF mixes. Preplant SME indicated pH was within normal limits (Table 17). The EC of ADDF mixes was high, but considered tolerable for poinsettias. PT extracts collected on September 11 showed that pH had decreased to 4.4 to 4.6 in ADDF mixes, probably as the result of sulfur oxidation. The EC in ADDF mixes had increased to 6.2 to 7.0. Plants in the ADDF:COIR mixes exhibited chlorotic mottling of leaves. ADDF mixes were leached with water on September 11, 12 and 13 and treated with flowable lime on September 16 and 19. However, by September 19 the leaves of plants in ADDF media were progressing from chlorosis to necrosis. The damage persisted and the experiment was terminated on October 2. Although leaching and flowable lime applications had reduced the EC and increased the pH to within normal limits, the crop was a total loss.

RESULTS

Crop production trials to evaluate ADDF potting mixes were conducted at different locations. Irrigation and fertilization practices were the same as for crops grown in standard commercial potting mixes.

At one grower location, ADDF potting mix produced a commercially acceptable crop of garden mums. In another grower trial, growth of a variety of bedding plants in ADDF potting mix was indistinguishable from commercial controls. In UConn trials, results with ADDF potting mixes were variable. With several crops ADDF potting mixes produced plants equal to or larger than the control, but with some crops plants grown in ADDF potting mixes were smaller than the control. Plant tissue samples had significantly greater P concentration with ADDF mixes than controls.

The most serious problem associated with the use of ADDF in potting mixes was pH management. As received, ADDF is alkaline in reaction and the alkalinity could be neutralized by mixing with sphagnum peat. If ADDF is mixed with coir, which is near neutral in reaction, elemental sulfur is recommended to acidify the mixture. However, the reaction of elemental sulfur is dependent on microbial activity, so is subject to considerable variability. Furthermore, pH of ADDF is not stable, as microbial conversion of ammonium to nitrate can lead to rapid acidification. As in the case of sulfur oxidation, the process is highly variable. In some trials this led to development of excessive acidity in mixes containing ADDF.

A preliminary analysis of various ADDF-containing media helped to identify some blends that were most similar to a standard peat-based mix for use in subsequent plant growth trials. Mixes that combined ADDF with other alternative media components such as coconut fiber (coir) and parboiled rice hulls (PBRH) were also evaluated to determine the adaptability of ADDF in a diversity of mixes. The media analysis showed that the physical properties, including porosity, water holding capacity and bulk density of mixes with peat-ADDF-perlite, peat-ADDF-PBRH, coir-ADDF-perlite and coir-ADDF-PBRH in a 2:2:1 ratio were similar to a peat-perlite greenhouse mix in a ratio of 4:1. Likewise, nursery mixes containing bark-ADDF-sand or bark-ADDF-perlite in a 4:2:1 ratio had similar physical properties to analogous mixes with peat in place of ADDF.

Mixes containing ADDF did, however, differ from peat-based mixes in some chemical properties. Raw ADDF has a high pH (7.5 or higher) whereas peat is generally acidic (below pH 5). The high pH of ADDF makes it unusable as a complete replacement for peat in greenhouse mixes unless it is amended with elemental sulfur. However, adjusting the pH with sulfur can be tricky. Fortunately, the preliminary media analysis revealed that when ADDF and peat are blended in 1:1 proportion they neutralize each other and arrive at a pH suitable for plant growth (around 6.0-6.5). However, when ADDF was mixed with near pH neutral coir, the final product had a pH slightly higher than ideal for plant growth (6.7-7.0). In a standard peat-perlite mix, lime is added both to raise the pH of the mix and to supply plants with calcium. In the ADDF-containing mixes, pH was in an acceptable range before liming so gypsum was used to add calcium without greatly changing the pH. Potting mixes containing ADDF had higher soluble salt content, greater alkalinity, and higher concentrations of nitrogen and phosphorus. They were also less stable, as pH sometimes changed rapidly during storage and use.

Under the supervision of Dr. Elliott, Jack Lamont, a UConn graduate student, conducted additional trials with poinsettia, woody plants, and herbaceous perennials and assessed the nutrient availability and physical characteristics of ADDF over time. Chapter 1 of Lamont's MS thesis included in the Appendix adds to the description of trial methodology and results.

SUMMARY

For most crops, at least one mix containing ADDF yielded plant growth results equal to or better than the plants grown in the standard peat based mix.

In some crops, such as viola, petunia, poinsettia, ninebark and cranberrybush viburnum, plants grown in an ADDF-containing mix were of much higher quality than those grown in the peat-based mix. The variability in results was likely due to the fact that all management decisions were based on established management practices for peat-based mixes. Slight differences between ADDF and peat likely necessitate slightly different growing practices to achieve optimal results from ADDF.

The results of physical and chemical evaluation of ADDF potting mixes support the conclusion that ADDF can substitute effectively for peat in potting mixes, and that nutrients in ADDF can help meet fertilizer requirements. Plant growth trials also support the potential for using ADDF as a peat substitute. We found that with some species ADDF potting mixes can produce crops equivalent or superior to a standard commercial potting mix. Further research would be required to determine if established irrigation and fertilization management could be modified to improve results with species that did not do as well in ADDF potting mixes. Skilled attention to chemical properties of ADDF mixes is required, which may present a challenge for management.

Project Partners and Funding

- CT RC&D: Project management, grant oversight and outreach
- Lynda Brushett, Ph. D. Cooperative Development Institute: Project Coordinator responsible for coordinating project tasks and deliverables.
- George Elliott, Ph. D. Associate Professor of Horticulture, University of Connecticut: Principal Investigator responsible for plant trials.
- Craig MacConnell, Washington State University, Whatcom County, Cooperative Extension Director, Research Consultant responsible for advising project investigators and farmers on ADDF potting mixes and protocols.
- Grower Direct: Trial site for greenhouse annuals; responsible for bench space, materials and staff.
- Freund Farm: Trail site; responsible for ADDF, bench space, materials and staff.
- Jaquier Farm: responsible for pick-up and delivery of ADDF to trial sites.
- UConn Floriculture Greenhouse: Trial site for annuals and woody perennials; responsible for bench space, materials and oversight.
- CT DEEP 319 Nonpoint Source Grant, funding

Description of Methods

Please refer to the report narrative and materials in the Appendix ie. Lamont Chapter 1, & QAPP materials.

Future Plans

Adoption of anaerobic digestion for dairy manure management will depend on economic and regulatory factors that overshadow the potential use of ADDF in potting mixes.

If market research indicates specific potential for ADDF potting mixes, then further work will be required to evaluate the characteristics of the ADDF available from different dairy operations so that they can be aggregated consistently and recipes will be fine tuned for specific uses. Since many growers prefer to purchase ready-made potting mix, an enterprise could be developed to blend and deliver bulk material. A high level of quality assurance would be required, as well as technical support for growers using the mix.

List of all Data Collected

1. DATA REFERENCED IN THE FINAL REPORT

- Tables 1, 2 & 4. Laboratory analysis of physical properties of ADDF
- Tables 3, 5 & 6. Laboratory analysis of chemical properties of ADDF
- Table 7. Physical properties of potting mixes used for Grower Direct Farm garden mum trial
- Table 8. Chemical properties of potting mix used for Grower Direct Farm garden mum trial
- Table 9. Chemical properties of ADDF potting mixes and control used in 2013 UConn trials.
- Table 10. Physical properties of ADDF-containing potting mixes and control used in 2013 UConn trials.
- Table 11. Effect of elemental sulfur additions on pH of ADDF and ADDF-containing mixes
- Table 12. PourThru and Saturated Media extracts of ADDF-containing mix collected during the course of the Grower Direct Farm garden mum trial.
- Table 13. Leaf tissue nutrient analysis of garden mums from Grower Direct Farm trial.
- Table 14. Shoot fresh weights of plants grown in ADDF-containing potting mixes and peat-perlite control from UConn bedding plant trial.
- Table 15. Shoot fresh weight of garden mums, saturated media and pourthru extracts from ADDF-containing potting mixes and peat-perlite control from UConn garden mum trial summer 2013.
- Table 16. Canopy volume of cyclamen grown in ADDF-containing potting mixes and peat-perlite control.
- Table 17. pH and EC of ADDF-containing potting mixes and peat-perlite control used in UConn poinsettia trial fall 2013.

2. LAMONT MS THESIS CHAP 1; PREVIOUSLY UNREPORTED DATA

- Table 1.1. Water retention and bulk density of ADDF-containing potting mixes and peat-perlite control used in UConn greenhouse crop trials.
- Table 1.2. Water retention and bulk density of ADDF-containing potting mixes and controls used in UConn nursery crop trials.
- Table 1.3. Volume loss of ADDF-containing potting mixes and controls used in UConn nursery crop trials.
- Table 1.4. Shoot tissue nutrient analysis of bedding plants from UConn greenhouse crop trials.
- Table 1.5. Canopy volume and maturity rating of garden mums grown in ADDF-containing potting mixes and peat-perlite control.
- Table 1.6. Shoot fresh and dry weights and height of poinsettias grown in ADDF-containing potting mixes and peat-perlite control at UConn Fall 2014.
- Table 1.7. Leaf tissue nutrient analysis of poinsettia from UConn Fall 2014 trial.
- Tab 1.8, 1.9, 1.10, 1.11, 1.12, Fig 1.15. Growth of herbaceous perennials (Brunnera, Coreopsis, Shasta Daisy, Liatris & Phlox) in BARK: ADDF: PERL potting mix compared to BARK: PEAT: PERL
- Figure 1.1. Shoot fresh weights of plants grown in ADDF-containing potting mixes and peat-perlite control from UConn bedding plant trial. (note; same data as in Table 14 of 2013 report with addition of data for cucumber).
- Figure 1.2. Shoot tissue phosphorus concentration of plants grown in ADDF-containing potting mixes and peat-perlite control from UConn bedding plant trial.
- Figure 1.4. Composite overview of of plants grown in ADDF-containing potting mixes and peat-perlite control from UConn bedding plant trial.
- Figure 1.6. Phosphorus concentration in PourThru extracts from ADDF-containing potting mixes and peat-perlite control in poinsettia trial at UConn Fall 2014.
- Figure 1.7. Overview of plants in poinsettia trial at UConn Fall 2014.
- Fig 1.8, 1.10, 1.11; Growth of woody plants (silky dogwood and button bush) in BARK: ADDF: SAND potting mix compared to BARK: PEAT: SAND
- Fig 1.9; P concentrations in PourThru extracts of BARK: ADDF: SAND potting mix compared to BARK: PEAT: SAND
- Fig. 1.12, 1.13; Growth of woody plant cuttings (ninebark, cranberry bush viburnum) in BARK: ADDF: SAND potting mix compared to BARK: PEAT: SAND
- Fig 1.16; Cumulation leaching of P from BARK: ADDF: PERL potting mix compared to BARK: PEAT: PERL planted with herbaceous perennials

Data Analysis

Refer to the Final Report Narrative and Appendix

Conclusions

The results of physical and chemical evaluation of ADDF potting mixes support the conclusion that ADDF can substitute effectively for peat in potting mixes, and that nutrients in ADDF can help meet fertilizer requirements.

Plant growth trials support the potential for using ADDF as a peat substitute. Further research would be required to determine if irrigation and fertilization management could be modified to improve results with species that did not do as well in ADDF potting mixes. Skilled attention to chemical properties of ADDF mixes is required, which may present a challenge for management.

PROBLEMS OR DIFFICULTIES EXPERIENCED AND HOW THEY WERE RESOLVED

The project was developed in 2009 and funded 2 years later. Work got underway in the fall of 2011 beginning with a site visit by Craig MacConnell, the Project's research consultant. MacConnell had done original research using amended digestate fibers as a substrate that could replace peat in growing annuals. MacConnell took digestate fibers from one dairy farm, amended the material and successfully grew petunias. The objective of this project was to replicate MacConnell's results using fibers from multiple dairy farms and amending the material to grow annuals, perennial and woody plants at three commercial greenhouse locations.

1. After visiting with MacConnell and learning more about his work beyond what had been published, we made several project modifications:
   a. Because woody plant growing media use very little peat and because MacConnell had never worked with any of these types of plants, we determined it would be more useful to organize trials with different annuals. This eliminated the need for the grower site at the nursery that specialized in woody plants. The planned site at Sunny Borders was replaced with UConn.
   b. Project review discussions recommended that the project focus more on annuals, the most largest user of peat in mixes (80-85% of potting material), and perennials, that uses about a 20% ratio of peat in a mix.
2. After a more than 4 month delay in invoice processing/payment, the Project research consultant dropped out of the project. Further delays in invoice processing/payment lead to an overall delay in getting the second round of trials organized. These delays were compounded by the renovation of the UConn greenhouses.
3. From October to December 2012 the project was on hold due to lack of funds and seasonal lag in greenhouse production activity. Cooperative Development Institute agreed to cover project expenses for materials, testing etc. in advance of reimbursement.
4. The project originally proposed locations at grower greenhouses as trial sites so that the growers would experience first hand the results of substituting peat with ADDF. However from a research perspective we decided it would be advisable to have a control site to account for any inadvertent grower induced error such as staff not watering plants or adding supplements properly, etc. and to provide opportunity for very close observations and adjustments. The UConn Floriculture Greenhouse was added to insure that a well-designed study is well-executed so that the project has good results to show growers
5. We learned that mixing fibers from different farms could introduce variability not present in the original research. As this study was designed for replication, it was preferable to conduct trials with fibers from one farm. We made a change made to source fiber from one farm, the Freund farm, only. The Jaquier farm provided transportation of fibers.
6. When we began organizing the trial locations, we discovered that during the period between when the proposal was written and when the project was funded, one of the project's commercial growers stopped mixing their own potting media. The grower's change to a pre-mix made the nursery no longer a viable research site as they were no longer a potential user of bulk ADDF. The grower was dropped from the project and replaced with the Freund farm as a site to grow spring bedding plants in another digestate product: cow pots.
7. These changes required an extension of the Project completion date to October 1, 2013. Trials at UConn allowed for more intensive research on dairy fiber mix formulation and nutrient supply and allow closer monitoring. Trials at the Freund Farm begin in the Spring 2013 and evaluated dairy

fiber mix in a small scale greenhouse producing a diverse mixture of bedding and garden plants.

8. Fibers were tested to compare potting mixes with dairy fiber substituted for peat moss in the standard mixes and based on those results, preceded to grower trials. A trial of dairy fiber potting mix for garden mums was set up at Grower Direct Farms 2012. While not able to start until the end of August 2013 due to comprehensive renovations, a concurrent trial was conducted at UConn. Potting mix was monitored at both sites and adjustments made as needed.
9. To catch up and to expand the amount of research (more species, more data) to be accomplished in a shorter time period, in 2013 the project decided to involve undergrad and graduate students. Funds were shifted to support these students and leveraged to secure a SARE grant.. A UConn graduate student conducted additional research on the following topics:
   a. Formulating potting mixes using dairy fiber as a substitute for peat moss with emphasis on providing desirable physical properties.
   b. Evaluating nutrient availability from dairy fiber in potting mixes with emphasis on nitrogen and phosphorus.
   c. Developing fertilization strategies to effectively utilize the nutrients provided by dairy fiber in potting mixes.

An undergraduate student assisted the project with routine analyses of samples, care of plants, obtaining samples and measurements in greenhouse and outdoor trials at UConn, and data entry.

EVALUATION

The project recipient(s) evaluated the effectiveness of the project though steering committee participation and input to the study design, through the participation of green house growers and dairy farmers in project trials and through feedback on presentations of project results.

RECOMMENDATIONS FOR CONTINUED ACTION

Further action is predicated on adoption of anaerobic digestors by CT dairy farmers. Efforts should be focused on developing an enterprise plan to produce potting mixes using ADDF and other locally available components such as composted bark. Market analysis should be used to determine what materials are most readily available and cost-effective. Once materials are identified, an optimum blend can be developed. Markets for ADDF mix could be bulk material delivered to greenhouses and nurseries or bagged mix for retail sales.

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Appendix

1. Tables 1-17
2. Figures 1-17
3. Chapter 1 of M.S. thesis by John Lamont. Contains supplemental data for trials reported in 2013, plus data collected in subsequent trials with poinsettia, woody plants, and herbaceous perennials.
4. Using ADDF in soilless potting mixes.
5. Presentation on using ADDF in soilless potting mixes.
6. Pre-publication drafts of 2 articles submitted to trade magazines.
7. George Elliott curriculum vita
8. Digested Dairy Manure
9. Peat Usage
10. QAPP
11. Outreach flyers

Soil and Plant Laboratory, Inc.

www.soilandplantlaboratory.com

1101 South Winchester
Suite G-173
San Jose CA 95128
408-727-0330 phone
408-727-5125 fax

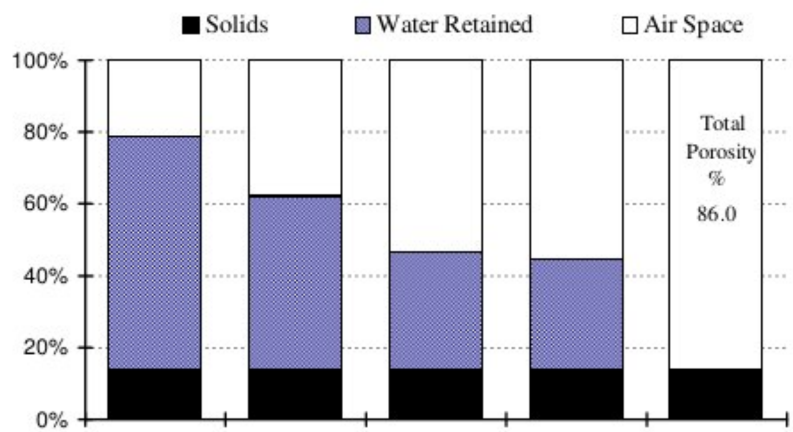
PHYSICAL PROPERTIES (A06)

Suisun, CA 94585
24 Hyde Ave.
Vernon, CT 06066

Lab No. 86825

Sample Number: 11-333-0013
Designation: Dairy Manure Fiber

Date Received: 11/29/2011



Centibars suction	C.C.*	2	10	50	Dry
Density, lbs./cu.ft.	47.5	36.8	27.1	25.8	6.7
Water Retention, vol. %	64.9	48.3	32.7	30.7	0.0
Air Space, vol. %	21.1	37.7	53.3	55.3	86.0
Water Retention, % dry wt	585				

Readily available water, vol. %
(Container capacity to 50 cb) 34.2
* Container capacity determined using 4 inch column

Potentially available water, vol% 49.6
(Readily available plus half
that held at 50 cb)

Saturated Bulk Density 60.2 lbs./cu. ft.

	C.C.*	2	10	50	Dry
Solids	13.97435897	13.97435897	13.97435897	13.97435897	13.97435897
Water Retained	64.94842525	48.30532213	32.71708683	30.70028011	0
Air Space	21.07721577	37.7203189	53.30855419	55.32536091	86.02564103

APPENDIX 1-TABLE 1

Soil and Plant Laboratory, Inc.

www.soilandplantlaboratory.com

PHYSICAL PROPERTIES (A06)

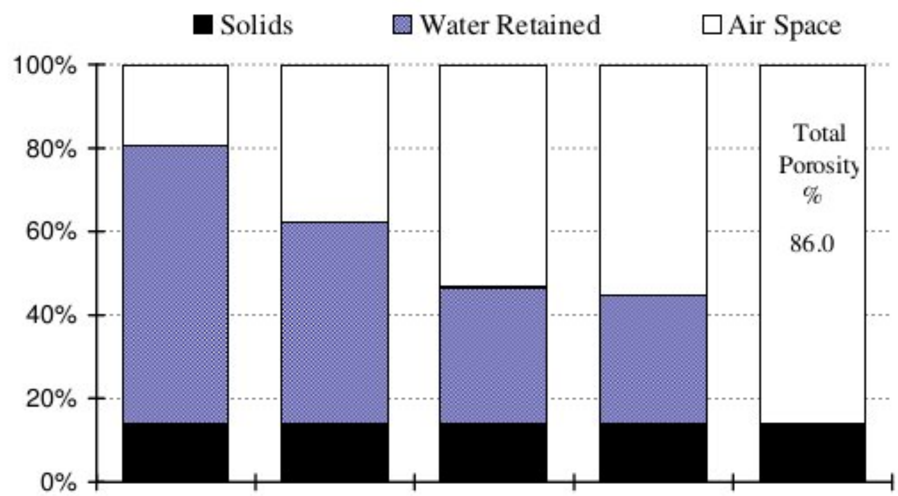
4741 E. Hunter Ave., Suite A
Anaheim, CA 92807
714-282-8777 phone
714-282-8575 fax

Easter CT RC&D
24 Hyde Ave.
Vernon, CT 06066

Lab No. 86825

Sample Number: 11-333-0013
Designation: Dairy Manure Fiber

Date Received: 11/29/2011



Centibars suction	C.C.*	2	10	50	Dry
Density, lbs./cu.ft.	48.9	36.8	27.1	25.8	6.7
Water Retention, vol. %	66.6	48.3	32.7	30.7	0.0
Air Space, vol. %	19.5	37.7	53.3	55.3	86.0
Water Retention, % dry wt	563				

Readily available water, vol. %
(Container capacity to 50 cb) 35.9
* Container capacity determined using 6 inch column

Potentially available water, vol% 51.2
(Readily available plus half
that held at 50 cb)

Saturated Bulk Density 60.2 lbs./cu. ft.

APPENDIX 1-TABLE 2

Soil & Plant Laboratory, Inc.
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SOIL ANALYSIS

Send To :	Project :	
EASTER CT RC&D AREA, INC. 24 HYDE AVE VERNON CT 06066		Report No : 11-333-0012 Cust No : 05377 Date Printed : 12/06/2011 Date Received : 11/29/2011 Page : 1 of 1 Lab Number : 17250

Sample Id : **ANEEROBICALLY DIGESTED DAIRY MANURE FIBER**

SATURATION EXTRACT - PLANT SUITABILITY

Test	Result	Effect on Plant Growth: Negligible	Sensitive Crops Restricted	Many Crops Restricted	Only Tolerant Crops Satisfactory	Few Crops Survive
Salinity (ECe)	1.9 dS/m					
Sodium Adsorption Ratio (SAR) *	6.65					
Boron (B)	0.45 ppm					
Sodium (Na)	10.8 meq/L					
Chloride (Cl)						
Carbonate (CO3)						
Bicarbonate (HCO3)						
Fluoride (F)						

* Structure and water infiltration of mineral soils potentially adversely affected at SAR values higher than 6.

Test	Result	Strongly Acidic	Moderately Acidic	Slightly Acidic	Neutral	Slightly Alkaline	Moderately Alkaline	Strongly Alkaline	Qualitative Lime
pH	7.4 s.u.								None

EXTRACTABLE NUTRIENTS

Test	Result	Sufficiency Factor	SOIL TEST RATINGS: Very Low	Low	Medium	Optimum	Very High
Available-N	98 ppm	0.1					
Phosphorus (P) - Olsen	358 ppm	0.8					
Potassium (K)	4959 ppm	3.6					
Potassium - sat. ext.	9.5 meq/L						
Calcium (Ca)	2569 ppm	0.4					
Calcium - sat. ext.	2.9 meq/L						
Magnesium (Mg)	2045 ppm	2.0					
Magnesium - sat. ext.	2.4 meq/L						
Copper (Cu)	3.2 ppm	0.7					
Zinc (Zn)	268 ppm	15.2					
Manganese (Mn)	51 ppm	1.3					
Iron (Fe)	55 ppm	0.3					
Boron (B) - sat. ext.	0.45 ppm	1.5					
Sulfate - sat. ext.	2.6 meq/L	0.9					
Exch Aluminum							

NO3-N	NH4-N	Total Exchangeable Cations(TEC)
5 ppm	93 ppm	353 meq/kg

Cu, Zn, Mn and Fe were analyzed by DTPA extract.

PARTICLE SIZE ANALYSIS

Half Sat	Organic Matter	Gravel Coarse 5-12	Gravel Fine 2-5	Sand Very Coarse 1-2	Sand Coarse 0.5-1	Sand Med. to Very Fine 0.05-0.5	Silt .002-.05	Clay 0-.002	USDA Soil Classification
373 %									

(Sand and Silt/Clay columns: Weight Percent of Sample Passing 2mm Screen)

Graphical interpretation is a general guide. Optimum levels will vary by crop and objectives.

APPENDIX 1-TABLE 3

JR PETERS Laboratory

POROMETER ANALYSIS

Submittor	Uconn/PSLA Dept.		Account No.	5200065
Address	1376 Storrs Rd.		Submission No.	94020
	Unit 4067			
	Storrs, CT 06269			
email	george.elliot@uconn.edu			
Fax				

Date Received 5/23/2012
Date Completed 5/31/2012

Lab ID	Sample ID	Total Porosity%	Container Capacity%	Air Space%	Bulk Density	Moist Bulk Density	% Moisture	Initial % Moisture
3122991	PC3	68.87	60.94	7.93	25.77	47.55	59.57	45.80
3122992	PCF	64.52	57.72	6.79	34.41	51.54	51.14	33.23
3122993	ADDF	72.46	65.37	7.09	7.33	22.96	84.78	68.07

Explanation of Terms:

Total Porosity	Calculated amount of total pore space in the sample.
Container Capacity	Calculated amount of water the sample will hold against gravity.
Air Space	Calculated amount of space in the sample that will not hold water against gravity.
Bulk Density	Calculated density of the material when completely dry.
Moist Bulk Density	Calculated density of the material after draining excess water.
% Moisture	Calculated moisture of the sample after soaking.
Initial % Moisture	Calculated moisture of the sample as received.
% Working Moisture	Additional moistening of sample was required to facilitate analysis.

Released by Tina Wolf
Lab Manager

APPENDIX 1-TABLE 4

Saturated media extracts of (ADDF, a mix of 40% ADDF: 40% PEAT: 20% PERL
and a mix of 80% PEAT: 20% PERL

			ADDF	GDF	GD2	NORMAL RANGE	
pH			7.76 H	5.82	6.03	5.2	6.3
Soluble Salts	dS/m		3.78 H	1.89	0.72 L	0.75	3.5
Nitrate	ppm	NO3-N	8.31 L	2.13 L	3.16 L	35	180
Ammonia	ppm	NH4-N	78.4 H	17.8	1.16	0	20
Phosphorus	ppm	P	49.4	104 H	0.347 L	5	50
Potassium	ppm	K	602 H	223	2.78 L	35	300
Calcium	ppm	Ca	36.4 L	53.7	44.5	40	200
Magnesium	ppm	Mg	33.4	39.3	45.3	20	100
Sulfur	ppm	S	73.5	151	115	50	250
Boron	ppm	B	0.924 H	0.525 H	0.084	0.05	0.5
Iron	ppm	Fe	1.3	0.341	0.11 L	0.3	3
Manganese	ppm	Mn	0.433	0.373	0.132	0.02	3
Copper	ppm	Cu	0.236	0.134	0.089	0.001	0.5
Zinc	ppm	Zn	1.84	0.888	0.245 L	0.3	3
Molybdenum	ppm	Mo	0.088	0.003 L	0.002 L	0.01	0.1
Aluminum	ppm	Al	0.382	0.513	0.252		
Sodium	ppm	Na	327	164	35.8		
Chlorides	ppm	Cl	123	147	25		

APPENDIX 1-TABLE 5

Soil Nutrient Analysis Laboratory

Soil Nutrient Analysis Laboratory, 6 Sherman Place, Unit 5102, Storrs, CT 06269-5102 • Phone: 860-486-4274, Fax: 860-486-4562
Location: Union Cottage, Depot Campus, Mansfield

PLANT ANALYSIS RESULTS

Client: Dr. Elliott
ABL
UCONN
Storrs, CT 06269

Copy to:

Date Received: 3-4-2013
Date Processed: 3-11-2013

Crop:

Sample ID: N1

Lab ID: T13-178

Plant Nutrient	Sample Results	Sufficiency Range
Nitrogen (N) % Dry Weight	NA	
Phosphorus (P) % Dry Weight	0.36	
Potassium (K) % Dry Weight	2.39	
Calcium (Ca) % Dry Weight	1.50	
Magnesium (Mg) % Dry Weight	0.41	
Boron (B) PPM Dry Weight	81.7	
Copper (Cu) PPM Dry Weight	31.6	
Iron (Fe) PPM Dry Weight	711	
Manganese (Mn) PPM Dry Weight	116.6	
Molybdenum (Mo) PPM Dry Weight	1.8	
Zinc (Zn) PPM Dry Weight	471	
Non-Essential Elements		
Sodium (Na) PPM Dry Weight	294	
Aluminum (Al) PPM Dry Weight	155.6	
Lead (Pb) PPM Dry Weight	0.6	

ND: Non Detectable

From: Mills, H. A. and J. B. Jones, Jr. 1996. Plant Analysis Handbook II. MicroMacro Publishing. Athens, Georgia.

Soil Nutrient Analysis Laboratory

Soil Nutrient Analysis Laboratory, 6 Sherman Place, Unit 5102, Storrs, CT 06269-5102 • Phone: 860-486-4274, Fax: 860-486-4562
Location: Union Cottage, Depot Campus, Mansfield

PLANT ANALYSIS RESULTS

Client: Dr. Elliott
ABL
UCONN
Storrs, CT 06269

Copy to:

Date Received: 3-4-2013
Date Processed: 3-11-2013

Crop:

Sample ID: O1

Lab ID: T13-179

Plant Nutrient	Sample Results	Sufficiency Range
Nitrogen (N) % Dry Weight	NA	
Phosphorus (P) % Dry Weight	0.50	
Potassium (K) % Dry Weight	3.16	
Calcium (Ca) % Dry Weight	1.97	
Magnesium (Mg) % Dry Weight	0.68	
Boron (B) PPM Dry Weight	96.6	
Copper (Cu) PPM Dry Weight	44.4	
Iron (Fe) PPM Dry Weight	1038.5	
Manganese (Mn) PPM Dry Weight	189.4	
Molybdenum (Mo) PPM Dry Weight	1.2	
Zinc (Zn) PPM Dry Weight	768.9	
Non-Essential Elements		
Sodium (Na) PPM Dry Weight	577	
Aluminum (Al) PPM Dry Weight	220.2	
Lead (Pb) PPM Dry Weight	24.6	

ND: Non Detectable

From: Mills, H. A. and J. B. Jones, Jr. 1996. Plant Analysis Handbook II. MicroMacro Publishing. Athens, Georgia.

JR PETERS Laboratory

POROMETER ANALYSIS

Submittor	Uconn Plant Science	Account No.	45508027
Address	1376 Storrs Rd.	Submission No.	94310
	Unit 4067		
	Storrs, CT 06269		
email	george.elliot@uconn.edu		
Fax			

Date Received 7/25/2012
Date Completed 8/1/2012

Lab ID	Sample ID	Total Porosity%	Container Capacity%	Air Space%	Bulk Density	Moist Bulk Density	% Moisture	Initial % Moisture
3124067	GDF	70.38	61.11	9.26	6.28	17.09	85.85	63.24
3124068	GD2	73.74	65.48	8.26	5.03	13.49	88.94	62.71

Explanation of Terms:

Total Porosity	Calculated amount of total pore space in the sample.
Container Capacity	Calculated amount of water the sample will hold against gravity.
Air Space	Calculated amount of space in the sample that will not hold water against gravity.
Bulk Density	Calculated density of the material when completely dry.
Moist Bulk Density	Calculated density of the material after draining excess water.
% Moisture	Calculated moisture of the sample after soaking.
Initial % Moisture	Calculated moisture of the sample as received.
% Working Moisture	Additional moistening of sample was required to facilitate analysis.

Released by Tina Wolf
Lab Manager

APPENDIX 1-TABLE 7

Chemical analysis of aqueous extracts of potting mixes evaluated in summer 2012.

			GDF-SME		GDF-PT1		GDF-PT2		DCF-SME		DCF-PT		NORMAL RANGE
pH			5.44		4.49	L	5.92		6.79	H	6.74	H	5.2 - 6.3
Soluble Salts	mmho		0.79		1.59		1.79		1.53		2.17		0.75 - 3.5
Nitrate	ppm	NO3-N	9.89	L	19.3	L	1.86	L	18.1	L	30.7	L	35 - 180
Ammonia	ppm	NH4-N	8.26		19.1		22.6	H	2.11	5	2.89		0 - 20
Phosphorus	ppm	P	51	H	94.7	H	109	H	66	H	70.2	H	5 - 50
Potassium	ppm	K	105		209		212		272		394	H	35 - 300
Calcium	ppm	Ca	18.3	L	47.5		78.8		12.7	L	17.1	L	40 - 200
Magnesium	ppm	Mg	12.2	L	32.5		45.8		9.01	L	13.4	L	20 - 100
Sulfur	ppm	S	31.9	L	77.1		149		18.6	L	27.7	L	50 - 250
Boron	ppm	B	0.374		0.305		0.295		0.322		0.263		0.05 - 0.5
Iron	ppm	Fe	0.318		0.675		0.545		0.601		0.571		0.30 - 3.0
Manganese	ppm	Mn	0.315		1.02		1.1		0.101		0.155		0.02 - 3.0
Copper	ppm	Cu	0.178		0.336		0.218		0.215		0.225		0.001 - 0.5
Zinc	ppm	Zn	0.378		0.436		0.512		0.527		0.323		0.30 - 3.0
Molybdenum	ppm	Mo	0.002	L	0	L	0.003	L	0.006	L	0.004	L	0.01 - 0.1
Aluminum	ppm	Al	0.355		0.716		0.859		0.182		0.202		N/A
Sodium	ppm	Na	64.5		111		126		138		180		N/A
Chlorides	ppm	Cl	93.5		155		154		161		153		N/A

APPENDIX 1-TABLE 8

SME analysis of potting mixes used in Spring 2013 trials

Potting Mix	pH	Electrical Conductivity	Ca	Mg	P	K	Cu	B	Fe	Mn	Zn
		dS / m					mg / L				
Control	5.9	0.63	41	52.7	0.07	2.3	0.09	0.06	0.13	0.04	0.18
ADDF: PEAT: PERL	6.4	2.14	275	66.6	33.3	160.6	0.04	0.37	0.23	0.57	0.71
ADDF: PEAT:PBRH	6.0	2.50	324	78.6	45.2	224.6	0.06	0.51	0.41	1.33	1.02

APPENDIX 1-TABLE 9

Initial physical & chemical properties of potting mixes formulated with anaerobically digested dairy fiber.

	Water retention		Air porosity		Bulk density						
Mix	Effective Capacity	Container Capacity	at effective capacity	at container capacity	Dry	Wet	pH	Electrical conductivity	NH4-N	NO3-N	PO4-P
					kg/m^3			dS/m		mg/L	
CONTROL	67.0% a	73.5% a	15.5% c	9.0% c	0.09 d	0.77 b	5.16	1.1	13	35.6	5.9
ADDF:PEAT:PERL	67.5% a	74.0% a	14.0% c	8.0% c	0.14 c	0.81 a	6.91	3.2	-2	3.4	1.5
ADDF:PEAT:PBRH	62.0% b	72.0% a	25.0% a	15.5% b	0.15 c	0.77 b	6.84	3.5	-2	3.5	5.5
ADDF:COIR:PERL	50.5% c	57.0% b	20.0% b	13.5% c	0.26 b	0.76 bc	6.12	2.7	-0.2	3.6	2.7
ADDF:COIR:PBRH	45.5% d	51.5% c	26.5% a	20.5% a	0.28 a	0.73 c	6.68	3.3	-1.4	3.5	3.7

means followed by the same letter are not significantly different at $p = 0.05$

APPENDIX 1-TABLE 10

Effect of sulfur addition and incubation on pH in ADDF and mixes.

S_0 addition g/L	MIX	Days of incubation 1	4	6	11	14	21
2	ADDF	8.60	8.11	7.46	6.57	6.09	
2	ADDF:PEAT:PERL	5.99	5.87	5.69	4.98	4.70	4.43
2	ADDF:PEAT:PBRH	5.30	5.50	4.85	4.32	4.14	4.16
2	ADDF:COIR:PERL	7.21	7.57	6.43	5.54	5.44	5.41
2	ADDF:COIR:PBRH	6.94	6.90	6.62	5.54	5.35	5.23
4	ADDF	8.69	8.11	6.43	5.44	5.16	
4	ADDF:PEAT:PERL	5.64	5.59	5.32	4.70	4.50	4.25
4	ADDF:PEAT:PBRH	5.64	5.78	5.22	4.51	4.31	4.16
4	ADDF:COIR:PERL	7.21	7.09	6.25	4.23	4.87	4.96
4	ADDF:COIR:PBRH	6.77	7.27	6.71	5.82	5.53	5.32
6	ADDF	8.69	7.94	6.25	5.26	5.14	
6	ADDF:PEAT:PERL	5.90	5.59	5.59	5.07	4.59	4.60
6	ADDF:PEAT:PBRH	5.50	5.41	5.04	4.23	4.12	4.16
6	ADDF:COIR:PERL	6.94	6.99	6.16	5.26	4.97	4.96
6	ADDF:COIR:PBRH	6.94	6.90	6.62	5.35	5.06	5.23

APPENDIX 1-TABLE 11

Field samples from Grower Direct Garden Mum Trial

Sample ID	Extraction	EC	pH	NO3-N	NH4-N	PO4-P
		dS/m			mg/L	
2012-07-23	SME	0.46	5.3	0.41	9.9	22.8
2012-08-14	PT	0.56	5.6	44	11	9.7
2012-08-21	SME	0.37	5.6	22	6.5	4.3
2012-08-29	PT	1.2	5.4	82	6.3	12.8

data are means of 4 to 6 individual extractions at each date

APPENDIX 1-TABLE 12

Garden Mum leaf tissue analysis

Element	tissue concentration	normal limits*
%N	6.0	4.0 - 6.5
P %	0.7	0.25 - 1.0
K %	5.1	3.5 - 6.5
Ca %	1.2	0.5 - 2.0
Mg %	0.7	0.3 - 0.6
B mg/kg	48	25 - 100
Cu mg/kg	15	5 - 30
Fe mg/kg	193	50 - 300
Mn mg/kg	328	30 - 350
Mo mg/kg	13	n/a
Zn mg/kg	107	15 - 30
Al mg/kg	11	n/a
Pb mg/kg	0	n/a
Na mg/kg	346	n/a

*Plant Analysis Handbook

APPENDIX 1-TABLE 13

Plant growth and phosphorus accumulation in potting mixes containing anaerobically digested dairy fiber
Means in a column within species followed by the same letter are not significantly diffent at the 0.05 level.

Pansy	Fwt (g)		Tissue P conc. (μg/g)	
	Mean *	Stdev	Mean *	Stdev
CONTROL	5.55 a	0.89	553 b	42.9
ADDF:PEAT:PERL	5.42 a	1.20	1080 a	27.7
ADDF:PEAT:PBRH	4.21 b	1.24	1086 a	12.5

Viola (CowPots)	Fwt (g)		Tissue P conc. (μg/g)	
	Mean *	Stdev	Mean *	Stdev
CONTROL	5.35 b	1.06	722.08 b	41.3
ADDF:PEAT:PERL	10.57 a	2.47	935.03 a	5.1
ADDF:PEAT:PBRH	10.16 a	1.68	988.66 a	24.1

Petunia	Fwt (g)		Tissue P conc. (μg/g)	
	Mean *	Stdev	Mean *	Stdev
CONTROL	4.89 c	0.70	299.80 c	31.8
ADDF:PEAT:PERL	11.08 a	0.87	844.40 b	7.9
ADDF:PEAT:PBRH	7.87 b	1.16	898.13 a	19.8

Geraniums (from seed)	Fwt (g)		Tissue P conc. (μg/g)	
	Mean *	Stdev	Mean *	Stdev
CONTROL	9.09 a	0.96	306.58 b	4.2
ADDF:PEAT:PERL	6.23 b	1.83	903.35 a	7.6
ADDF:PEAT:PBRH	1.89 c	1.30	905.96 a	6.5

Geranium (from cuttings)	Fwt (g)		Tissue P conc. (μg/g)	
	Mean	Stdev	Mean*	Stdev
CONTROL	36.58	8.60	483.56 c	18.7
ADDF:PEAT:PERL	41.40	4.80	738.74 b	32.4
ADDF:PEAT:PBRH	36.30	4.41	846.13 a	32.1

APPENDIX 1-TABLE 14

Results from Garden Mum trial summer 2013

I. Plant growth

Final Harvest	Vol (dm^3)		Fwt (g/plant)	
	Mean	Stdev	Mean	Stdev
CONTROL	15.46	1.96	611	36
ADDF:PEAT:PERL	13.34	2.73	527	56
ADDF:PEAT:PBRH	9.91	2.78	460	67
ADDF:COIR:PERL	11.60	1.72	512	26
ADDF:COIR:PBRH	9.20	1.39	402	50

II. Nutrient analyses of potting mix extracts

Mid Crop SME

	pH		EC		ppm NH4 - N		ppm PO4 - P		ppm NO3 - N	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
CONTROL	6.52	0.12	0.05	0.06	-2.52	0.19	0.47	0.07	8.14	5.18
ADDF:PEAT:PERL	6.35	0.08	1.14	0.26	-1.66	0.31	2.95	0.50	6.67	3.78
ADDF:PEAT:PBRH	6.42	0.12	1.35	0.54	-1.40	1.17	3.87	0.83	7.82	4.29
ADDF:COIR:PERL	6.59	0.07	0.92	0.35	-1.98	0.44	1.47	0.23	9.64	3.11
ADDF:COIR:PBRH	6.70	0.16	0.78	0.04	-1.58	0.47	3.03	0.25	6.28	1.98

Final SME

	pH		EC		ppm NH4 - N		ppm PO4 - P		ppm NO3 - N	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
CONTROL	6.35	0.16	0.22	0.03	1.69	0.51	1.63	0.11	9.12	1.53
ADDF:PEAT:PERL	6.98	0.14	0.77	0.13	0.66	0.17	1.98	0.06	2.42	0.53
ADDF:PEAT:PBRH	6.89	0.27	1.22	0.33	0.76	0.43	3.08	0.84	1.44	0.21
ADDF:COIR:PERL	7.20	0.10	0.84	0.09	0.35	0.18	1.88	0.10	1.69	0.67
ADDF:COIR:PBRH	7.26	0.05	0.38	0.07	0.41	0.41	2.12	0.08	0.91	0.49

Pour Throughs

ppm NH4 - N

	11-Jul		18-Jul		12-Aug		30-Sep	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
CONTROL	11.24	7.64	14.57	5.03	1.58	1.81	-1.92	1.33
ADDF:PEAT:PERL	6.21	5.35	15.75	5.41	11.11	9.43	-2.58	0.19
ADDF:PEAT:PBRH	1.92	5.48	14.53	1.41	13.11	5.31	-2.43	0.33
ADDF:COIR:PERL	-1.48	1.28	12.19	3.14	11.71	1.33	-2.43	0.19
ADDF:COIR:PBRH	-1.79	0.14	11.87	4.26	10.94	4.15	-1.22	1.70

ppm NO3 - N

	11-Jul		18-Jul		12-Aug		30-Sep	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
CONTROL	116.54	53.62	39.34	8.80	21.66	4.47	13.43	5.59
ADDF:PEAT:PERL	44.64	19.08	33.28	3.51	15.42	10.77	6.81	2.46
ADDF:PEAT:PBRH	20.00	11.41	29.58	4.19	37.31	9.74	12.24	3.06
ADDF:COIR:PERL	13.72	10.72	29.28	3.77	30.90	0.86	11.82	4.89
ADDF:COIR:PBRH	7.49	2.43	25.73	11.79	32.51	9.22	26.07	12.44

ppm PO4 - P

	11-Jul		18-Jul		12-Aug		30-Sep	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
CONTROL	6.42	2.10	2.34	0.36	4.68	1.50	0.53	0.14
ADDF:PEAT:PERL	14.61	3.98	4.14	1.97	8.08	7.97	0.57	0.11
ADDF:PEAT:PBRH	3.40	0.50	3.44	0.59	9.12	6.96	0.68	0.19
ADDF:COIR:PERL	1.39	0.11	3.04	0.65	9.45	0.45	0.60	0.25
ADDF:COIR:PBRH	2.09	0.13	2.24	0.23	8.95	2.65	0.60	0.33

APPENDIX 1-TABLE 15

Mix	Canopy volume cm3	
CONTROL	925	a
ADDF:PEAT:PERL	1103	a
ADDF:PEAT:PBRH	837	a
ADDF:COIR:PBRH	467	b
ADDF:COIR:PERL	226	b

APPENDIX 1-TABLE 16

	SME				PT extracts			
	preplant		Oct 2		Sept 11		Oct 2	
Mix	pH	ec	pH	EC	pH	EC	pH	EC
Control	5.94	0.98	6.08	2.00	6.21	2.49	6.54	1.09
ADDF:PEAT:PERL	5.37	3.30	5.61	1.75	4.63	6.16	5.42	2.30
ADDF:PEAT:PBRH	5.74	3.60	5.61	1.88	4.64	7.00	5.85	2.30
ADDF:COIR:PERL	6.22	3.90	5.89	2.00	4.36	6.22	5.70	2.30
ADDF:COIR:PBRH	5.41	3.70	6.45	2.00	4.40	6.46	5.65	2.10

APPENDIX 1-TABLE 17

APPENDIX 2-FIGURE 1

APPENDIX 2-FIGURE 2

APPENDIX 2-FIGURE 3

APPENDIX 2-FIGURE 4

APPENDIX 2-FIGURE 5

APPENDIX 2-FIGURE 6

APPENDIX 2-FIGURE 7

APPENDIX 2-FIGURE 8

APPENDIX 2-FIGURE 9

APPENDIX 2-FIGURE 10

APPENDIX 2-FIGURE 11

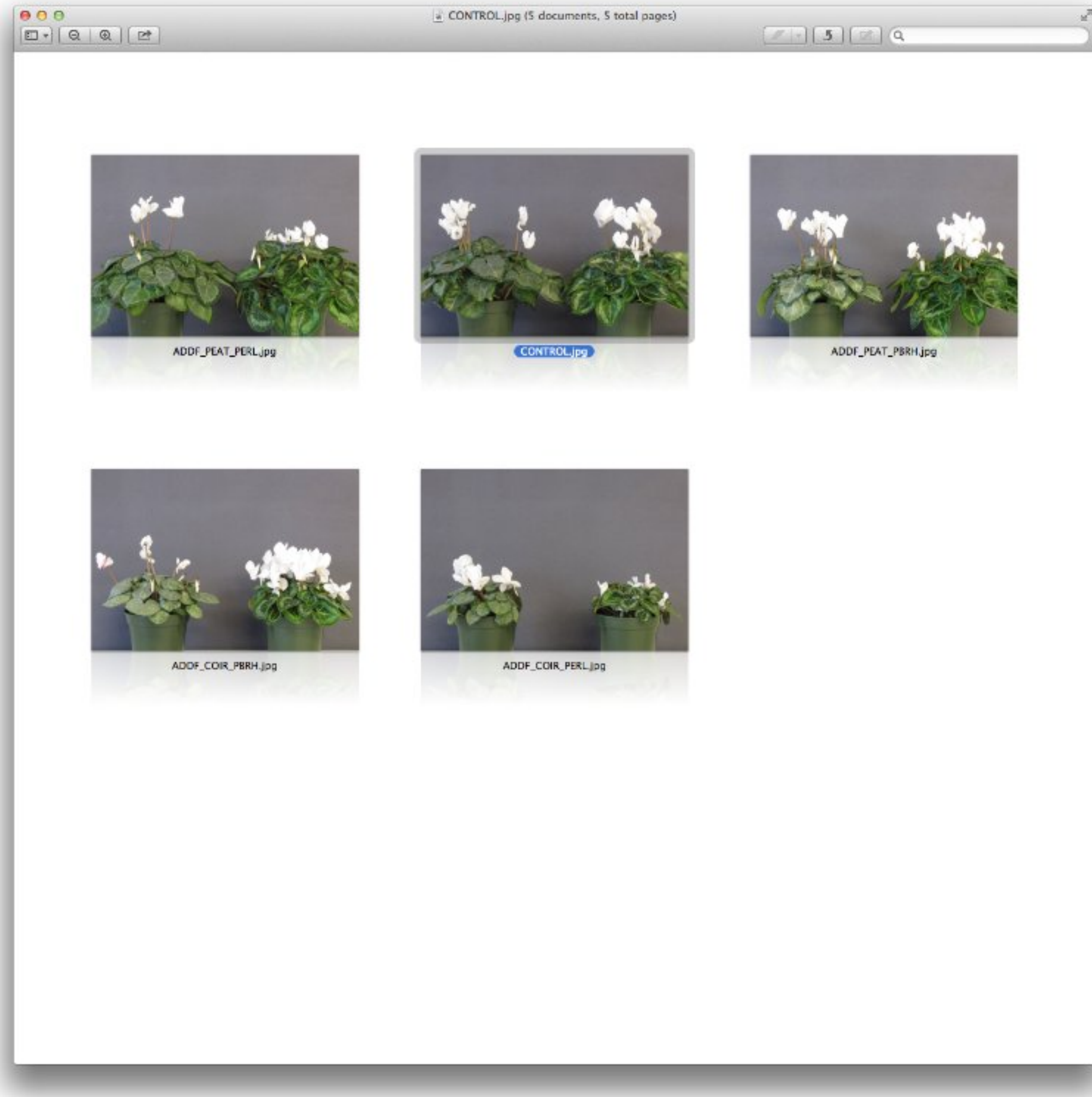
APPENDIX 2-FIGURE 12

APPENDIX 2-FIGURE 13

APPENDIX 2-FIGURE 14

APPENDIX 2-FIGURE 15

APPENDIX 2-FIGURE 16



APPENDIX 2-FIGURE 17

Chapter 1: Anaerobically digested dairy fiber as a substitute for peat in soilless potting media

1.1. Introduction

Container growing in context

Growing plants in containers offers a number of advantages over growing in the ground, most importantly the ability to precisely manipulate various attributes of the root zone to optimize plant growth. One of the most important manipulations of the root zone is the choice of growing media.

The purpose of this project is to evaluate anaerobically digested diary fiber (ADDF) as a sustainable alternative to peat in nursery container mixes. Peat is plant material, usually *Sphagnum* moss that has partially decomposed under low-nutrient, acidic, anaerobic conditions in bogs, leaving only a lignified cell wall structure. The skeletal cellular structure left by this partial decomposition remains intact under pressure and provides a great deal of inter- and intra-cellular pore space. The combination of a strong, lignified cell structure and extensive pore space provide peat with the physical and chemical characteristics which have made it such an important raw material for the horticulture industry for decades (Handreck, 1994). Recently, concerns about the sustainability of peat have been raised. Peatlands are wetland ecosystems that are both economically and ecologically important. Peatlands play an important role in water purification and are enormous carbon sinks. Mining of peat drastically alters the chemical, physical and biological composition of peatlands. Even after mined peatlands have been "restored" it takes several years to restore their ecological functionality. Although peatlands accumulate more peat over time, it is only about 0.5-1.0mm per year. Peat mining harvests from deep in the bogs and can represent hundreds of years of peat accumulation. Most peat is produced in cold, northern regions and must be shipped long distances to more temperate horticultural areas. These concerns have prompted a search for sustainable, local alternatives to peat (Chalker-Scott, viewed May 5, 2014).

One of these potential alternatives is anaerobically digested dairy fiber; a byproduct of methane extraction from dairy manure. Systems to extract methane and reduce odor from manure have been used since the 1970's and have been vastly improved in the ensuing decades. Selling methane as a biofuel generates additional income or on-site energy for livestock farmers and utilizes this carbon-rich greenhouse gas rather than losing it to the atmosphere and contributing to climate change.

Marketing ADDF as a useful horticultural material rather than simply manure could become yet another source of income for dairy farmers and provide a solution to same waste management problems associated with raw manure. Leaching of nutrients from accumulated manure is significant source of non-point source water pollution. If ADDF were used in a growing media, nutrients that would otherwise be lost as pollutants would be used for plant nutrition.

The potential for use of ADDF in growing media seems especially promising for the Northeast region. Agriculture in the Northeast is characterized by small diversified enterprises occupying a large portion of the industry. The diversity of farms and strong local agricultural networks in the Northeast make it an ideal locale for a product like ADDF potting mixes to be used widely.

Mixes containing ADDF have been used successfully to grow bedding plants (MacConnell and Collins, 2007) but currently, there is no information published about growing woody or herbaceous perennials in ADDF mixes. The robust nature of woody perennials makes them excellent choices for test subjects to grow in ADDF. The longer growing season of nursery crops presents a need to further investigate the physical properties of ADDF over time, particularly shrinkage.

The greenhouse, nursery and dairy industries are important to the New England economy and generate about one third of all agricultural cash receipts in New England (New England Agricultural Statistics, 2012). The environmental horticulture industry of New England represents almost 5 billion dollars, 11,900 firms, and 156,000 jobs and is growing. Nursery production represents a significant portion of this industry with almost half of New England horticultural firms engaged in some kind of production enterprise (New England Nursery Association, 2009). ADDF shows promise as a locally sourced, inexpensive, sustainable alternative to peat for growers in the Northeast.

Utilization of ADDF in soilless potting media (SPM) has the potential to greatly benefit the Northeastern dairy industry as well. The dairy industry of New England has historically been, and continues to be a vitally important part of the region's economy. Despite contributing over 3 billion dollars to the region's economy annually, the New England dairy industry has been in long term decline (Department of Economic and Community Development and Department of Agriculture. 2009). Methane extraction from manure shows great promise as a supplementary revenue source for Northeastern Dairy farmers but revenue generated by energy production alone is often not enough to offset the capital costs of constructing anaerobic digesters. If ADDF were proven as a high quality media component, it would be a value-added product to add to dairy profits. The demand for ADDF from growers would be an added incentive for dairy farmers to adopt the more sustainable anaerobic manure digestion systems (Lynda Brushett, Cooperative Development Institute, Barrington, New Hampshire, personal communication, May 1, 2014).

1.2. Literature Review

Research to find suitable, renewable alternatives to peat has been ongoing for decades. An alternative for peat should have similar physical and chemical properties as peat. Many potential alternatives are byproducts from agricultural and food industries. Agricultural and food byproducts are especially appealing because they are renewable resources and change the problem of waste management to an opportunity to generate revenue from a high-value horticultural product (Raviv, 2005).

Composts are often recommended as natural slow release fertilizer amendment in SPM but compost as direct or partial replacement for peat in SPM has also been researched extensively. Before the development of peat-based mixes composts often comprised a large proportion of potting mixes (Hankdrick & Black, 1994). Compost is organic material that has been stabilized using thermophilic, aerobic processes. A diversity of composts have been shown to possess physical and chemical properties within the acceptable range for plant growth. The most common limitation to using composts in SPM is a lack of physical and chemical stability which may lead to compaction and unpredictable nutrient release (Raviv, 2005). Despite these limitations, a wide variety of composts have been successfully used as replacements for peat in nursery SPM (Chong, 2005).

Cowpeat (Palm Harbor, FL) is a composted dairy manure product that has been tested extensively as an alternative to peat. Bedding (Shober et al., 2010), nursery (Shober et al., 2011) and foliage crops (Li et al., 2009) were produced successfully in Cowpeat-based media. Cowpeat-containing mixes had much higher phosphate loads in leachate samples for up to 88 days after planting. Concerns over phosphate pollution could limit the use of Cowpeat as a direct replacement for peat. Shober et al. (2011) suggested growers modify fertilization regimes to account for additional P supplied by CowPeat. The additional P in leachate from CowPeat-containing mixes likely came from calcium phosphate minerals used in nutritional suppliments for dairy cows. ADDF likely contains similar phosphate compounds.

Another composted dairy manure product, "dairy biofiber", is produced by separating liquid and solid fractions of dairy waste and composting the solid fraction. Dairy biofibers have been shown to be a suitable replacement for up to 30% of the peat in a SPM but high pH limited its use. While mixes with a combination of dairy biofiber with bark or PBRH had the highest concentrations of P in SME samples, the concentrations were still within an acceptable range for use in greenhouse media. It was suggested that dairy biofiber be blended with peat or amended with iron sulfate or elemental sulfur to maintain a suitable pH for plant growth (Evans et al., 2014).

Spent mushroom compost (SMC) is another proposed alternative to peat that shares many important characteristics with ADDF. Both ADDF and SMC are alkaline in reaction, have a high electrical conductivity and have similar physical properties to peat. Several trials have been done replacing peat with SMC in nursery SPM (Chong, 2005). The successful results from SMC trials and its similarity to ADDF show that ADDF has a strong potential as a replacement for peat in nursery SPM. Compaction (Chong et al., 1994) and chlorosis in some species (Chong et al., 1991) still present some challenges to using SMC as a direct peat replacement.

Tree-based products are another group of potential peat alternatives which has had quite a bit of research attention recently. A wide variety of hardwood and softwood species processed in a variety of ways have been evaluated as media components with mixed results. Media made with softwood species yielded much better growth results than hardwood-containing media (Murphy et al., 2007). Pine tree substrates (PTS), most frequently from loblolly pine (*Pinus taeda*), are widely studied tree-based greenhouse and nursery media component. PTS can be manufactured to have a designated particle size distribution which gives it particular physical properties appropriate for specific applications in media blends (Jackson et al., 2010). Manufacture procedures do need to be consistent to produce a product that will behave reliably (Field et al., 2014). Aged PTS produces higher quality plants than fresh PTS, likely due to pH stabilization and nutrient mineralization in the aging process (Gaches et al., 2012) and the possible presence of phytotoxic substances in fresh PTS (Taylor et al., 2013). The physical properties of PTS are consistent through the aging process (Taylor et al., 2013). PTS has been shown to have similar nitrification potential to conventional media when treated with lime (Taylor et al., 2012). PTS-containing media do however need higher fertilizer levels than conventional media to yield the same growth, likely due to microbial immobilization or greater porosity increasing leaching of nutrients (Wright et al., 2008).

The limitations of conventional composting have led to a search for alternative processes to produce more stable SPM components. Vermicompost has a number of qualities which may make it a beneficial media component. Vermicompost can be a significant source of nutrients however, it is much less biologically active than conventional composts, making it more chemically and physically stable (Ngo et al., 2013). Vermicompost also has a lower EC than conventional compost and is less prone to induce salt stress (Chaoui et al., 2003). Vermicompost made from tomato crop waste has been demonstrated to be a suitable replacement for up to 75% of the peat in SPM for *Calendula officinalis* and *Viola cornuta* (Belda et al., 2013). Media containing varying proportions up to a 2:1 ratio of vermicompost to coir yielded faster and greater yields of Swiss chard than either coir alone or a commercial potting media (Abbey et al., 2012).

Anaerobic digestion may prove to be another alternative way to process organic waste into a useful and stable SPM component. Previous research efforts with ADDF have shown promising results. Bedding plants grown in acidified ADDF-based media were of the same or better quality and size of those grown in peat-based media (MacConnell, 2007). In ADDF media trials at UConn, several varieties of bedding plants and vegetable seedlings grown in ADDF-containing media were of marketable quality. An outdoor ADDF media trial with garden mums had similarly positive results.

ADDF and ADDF products have already been successfully marketed as value-added horticultural products. Freund Farms (East Canaan, CT) manufacture biodegradable "Cowpots™" made from ADDF sell them nationally. Cenergy USA, Inc. (Little Rock, AR) produces "Magic Dirt™", a potting mix made from ADDF and composted forest products. Eco-Tek® (Rossville, IN) and Organix, Inc (Walla Walla, WA) have both been producing and selling dairy compost as a sustainable peat substitute for many years.

Some characteristics of ADDF do present challenges. ADDF has a high pH and interacts with different media components differently (Evans and Salazar, 2014). ADDF-containing media can be adjusted to an appropriate pH with the use of elemental sulfur (MacConnell, 2007) or with gypsum as demonstrated with previous trials in the Elliott lab. The varying reactions of ADDF to different media components is likely due to the biological activity of ADDF. A detailed evaluation of the biological activity of ADDF may aid in predicting how ADDF will react in a SPM.

Along with evaluating ADDF as a replacement for peat, it is also important to evaluate how ADDF works with other alternative media components which growers who may be interested in using ADDF as a peat replacement may also be interested in using. Parboiled rice hulls (PBRH) have been considered as a direct or partial replacement for either peat or perlite in SPM. Whole PBRH provide more pore space and are used as a replacement for perlite. Ground PBRH of various grades are used in place of peat. While the physical properties of whole and ground PBRH are similar to perlite and peat, respectively, some chemical attributes of ground PBRH likely make it unsuitable as a direct substitute for peat. PBRH contain high levels of P, K and silica. Silica acts as a base in PBRH-containing media and can raise the pH outside of the recommended range for plant growth. When PBRH are ground, significant amounts of P and K can be released and raise P and K levels outside the recommended range for SPM (Evans et al., 2011). Despite these obstacles, PBRH have been used successfully as a replacement for up to 30% of the perlite or 40% of the peat in SPM for a variety of bedding plants (Lopez and Currey, 2013) and up to 100% of the perlite in propagation mix for New Guinea impatiens (Lozez et al., 2013)

Coir is a renewable, fibrous byproduct of coconut processing. It can possess many similar physical properties to peat and has been tested widely as a partial or, in many cases, complete replacement for peat. There can be quite a bit of variability in coir based on how it is produced and the source it come from. Coir with different particle sized can be blended to produce a media that is appropriate for a specific application. Variability in physical properties due to particle size distribution and age of coir needs to be considered when using coir as a media component. High salinity in coir has been reported but is easily fixed by leaching. Despite the challenges in using coir, it has been shown to be an effective replacement for peat in many cases. (Nichols, 2007)

Research Objectives

1. To evaluate ADDF as a substitute for peat in a variety of soilless potting media formulations.
2. To evaluate nutrient availability in ADDF over time.
3. To evaluate physical characteristics of ADDF over time.

1.3. Materials and Methods

1.3.1. Media formulation and analysis

Five greenhouse mixes and four nursery mixes were formulated for use in the following trials. The greenhouse mixes contained peat-ADDF-perlite, peat-ADDF-parboiled rice hulls (PBRH), coir-ADDF-perlite and coir-ADDF-PBRH each in a 2:2:1 ratio amended with $4 g \cdot L^{-1}$ gypsum. A control mix was composed of peat and perlite in a 4:1 ratio amended with $2.5 g \cdot L^{-1}$ dolomitic lime. The nursery mixes contained bark-peat-sand, bark-ADDF-sand, bark-peat-perlite and bark-ADDF-perlite each in a 4:2:1 ratio. ADDF-containing mixes were amended with $4 g \cdot L^{-1}$ gypsum and peat-containing mixes were amended with $2.5 g \cdot L^{-1}$ dolomitic lime.

Preliminary SME samples were taken from each mix to measure initial pH, EC and nutrient concentration. SME samples were analyzed for ammoniacal nitrogen, nitrate nitrogen, and phosphate phosphorus using colorimetric methods (refs). pH and EC were measured using Twin pH/conductivity meters (Horiba Corp., Kyoto, Japan).

The physical properties of several ADDF-containing media were evaluated using the techniques described by Elliott (1992b): Media put in pots with known dimensions (truncated cone with height (H) of 120mm, bottom radius (R_b) of 30mm and top radius (R_t) of 40cm). Pots were weighed at the start of the trial and were subsequently irrigated, drained and weighed several times a week until the irrigated mass reached equilibrium. Equilibrated irrigated mass was used to derive effective water holding capacity (EWHC) using the equation (net weight after irrigation - initial dry weight). Pots were then saturated for 24 hours, then weighed before and after draining. Saturated and drained masses were used to derive container capacity (CCAP) using the equation (net weight after saturated and drained - initial dry weight). The volume of media in each pot was derived by measuring the height of the media in the pot and calculating volume as a function of height using the formula for a truncated cone: $V=\pi H(R_b^2+ R_b+ R_t+ R_t^2)$. Dry bulk densities were obtained by weighing a given volume of each media before and after drying and using the formula (initial dry weight)/(volume).

Physical properties and shrinkage of the bark-peat-sand and bark-ADDF-sand mixes were measured again at the end of the woody shrub growth trial to evaluate long-term use of ADDF for nursery crops.

1.3.2. Bedding Plants and Vegetable Seedlings.

Seedlings of pansy (*Viola* x *wittrockiana* ‘Karma White’), viola (*Viola cornuta* ‘Penny-jump-up’), petunia (*Petunia* x *hybrid* ‘Fuseable Vogue’), rooted cuttings of geranium (*Pelargonium* x *hortorum* ‘Patriot Red’) and seeds of cucumber were planted in pots containing the peat-ADDF-perlite, peat-ADDF-PBRH and control mixes described previously. Pansies and petunias were planted in Nu-Pots™ 4 (423ml capacity, 9.8cm tall) (Summit Platic Co., Tallmadge, OH), geraniums were planted in Nu-Pots™ 3 (321ml capacity, 8.9cm tall), violas were transplanted and cucumber seeds were sown in #3 CowPots™ (200ml capacity, 2 7/8” tall) (Freund Farm Inc., East Canaan, CT).

All bedding plant trials were completely random design (CRD) experiments. Pansies and violas had 32 plants per treatment, geranium and petunia had 16 plants per treatment and cucumber had 8 plants per treatment.

Plants were overhead irrigated without fertilizer for 12 days and then sub irrigated with constant liquid feed with 100 $mg \cdot L^{-1}$ N delivered from Plantex® 19N-0.9P-15.8K (Master Plant-Prod Inc. Brampton, ON) for the remainder of the experiment. Trials were conducted in a computer-controlled greenhouse covered with corrugated polycarbonate. Pansies and violas were grown with 62°F days and 58°F nights. Geranium, petunias and cucumbers were grown with 75°F days and 63°F nights.

Plants were harvested approximately 8 weeks after planting and fresh weight, dry weight and tissue nutrient concentrations were measured.

1.3.3. Mums.

Rooted cuttings of chrysanthemum (*Chrysanthemum morifolium* ‘Hankie Yellow’*)* were transplanted into 8” pans (Dillen 8x5” Pan, 2.88L capacity) (The HC Companies, Middlefield, OH) containing the peat-ADDF-perlite, peat-ADDF-PBRH, coir-ADDF-perlite, coir-ADDF-PBRH or the control mix described previously. One cutting was planted in each pan and grown, unpinched, outdoors with natural season lighting. Plants were overhead irrigated for one week and then drip irrigated with a constant liquid feed at the rate of 100 $mg \cdot L^{-1}$ N using a Plantex

19N-0.9P-15.8K. The experimental design of this trial was randomized complete block with 3 blocks and 8 plants per treatment per replication for a total of 120 pots.

The shoot fresh weight and volume were measured 12 weeks post-transplant. Canopy volume was estimated using the formula for a semi-ellipsoid ($\left(\frac{4}{3}\pi\left(\frac{w_1}{2}\right)\left(\frac{w_2}{2}\right)\left(\frac{H}{2}\right)/2\right)$) where w_1 and w_2 are the maximum and minimum diameters and *h* is the height from the top of the pot rim. Maturity was rated subjectively on a 3 point scale with a rating of 1 with 30% or fewer flowers open (Syngenta stages 0-1), 2 a plant with 31-69% flowers open (Syngenta stages 2-3) and with 3 representing a plant with 70% or more flowers open (Syngenta stages 4-5) (Syngenta Flowers Inc., 2015). Leaf tissue samples were obtained for nutrient analysis.

1.3.4. Cyclamen.

Cyclamen (*Cyclamen persicum*) 'Silver Heart White' and 'Winfall White' seedlings were transplanted into 4" pots (414ml capacity) containing the same media used previously in the garden mum trial, with six plants of each variety in each treatment. Each variety was arranged in a CRD.

Pots were placed in flood and drain trays and irrigated with 100 $mg \cdot L^{-1}$ N from Plantex 19N-0.9P-15.8K. At the end of the trial, approximately 9 weeks post-transplant, plants were evaluated qualitatively based on appearance and plant height and width were measured. Canopy volume was calculated as described in the chrysanthemum trial.

1.3.5. Poinsettias.

Rooted cuttings of poinsettia (*Euphorbia pulcherrima* ‘Classic Red’) were transplanted into Dillen 6” jumbo azalea pots (approximately 1.8L volume) containing the peat-ADDF-perlite and control mixes previously described with twelve plants of each variety in each treatment. Pots were placed in flood and drain trays and irrigated with 100 mg.L-1 N from Plantex 19N-0.9P-15.8K. At commercial maturity 15 weeks post-transplant, plant growth was evaluated qualitatively based on appearance. Shoot height, fresh weight and dry weight were measured and leaf tissue was analyzed. PourThru samples (Wright 1986) were taken approximately biweekly and analyzed for pH, EC and nutrient concentrations as previously described.

1.3.6. Woody Nursery Crops.

Liners of button bush (*Cephalanthus occidentalis*) and silky dogwood (*Cornus amomum*) were transplanted into #2 pots (7.3L volume) containing either the bark-ADDF-sand mix or the bark-peat-sand mix. Plants were fertilized with a top dressing of Osmocote 18-6-12 (Everris NA, Inc.) at a rate of 30g per pot. Plants were grown outdoors with natural season lighting and irrigated with drip irrigation during the first season’s growth. Plants were overwintered in an unheated hoop house. Plants were moved from the hoop house and forced out of dormancy in a double polyethylene film greenhouse with overhead irrigation. At the end of the first growing season, plant height, width, thickest stem caliper and number of shoots were measured. After leafing out at the beginning of the second season (approximately 10 weeks after being moved into greenhouse) plant height and shoot fresh weight and dry weight were measured. Leaf tissue samples were taken for nutrient analysis at the end of the first season before plants began to enter dormancy and at the beginning of the second season after plants had leafed out. Shrinkage of media was measured at the end of the first season and upon harvest at the beginning of the second season. Media physical properties including bulk density, porosity and water holding capacity were measured again upon harvest at the beginning of the second season. PourThru samples were taken regularly and analyzed for pH, EC and nutrient concentrations during the first season.

1.3.7. Woody Cuttings

Cuttings from ninebark (*Physocarpus opulifolius*) and cranberry bush viburnum (*Virburnum opulus*) were rooted in sand under intermittent mist with bottom heat. The rooted cuttings were then transplanted into 2.5” establishment pots (approximately 250 ml volume) and grown outdoors with overhead irrigation for one growing season. Plants were overwintered in a cold frame and forced out of dormancy in a greenhouse in early spring. Plants were evaluated after leafing out by measuring dry weight, height, above ground tissue concentrations and with a subjective visual evaluation.

1.3.8. Herbaceous Nursery Crops

A variety of representative herbaceous perennials were used in this trial. Plugs of brunnera (*Brunnera macrophylla* ‘Jack Frost’), Shasta daisy (*Lucanthemum superbum* ‘Whoops-a-Daisy’) and rooted cuttings of phlox (*Phlox paniculata* ‘David’), liatris (*Liatris spicata* ‘Kobold Original) and coreopsis (*Coreopsis verticillata* ‘Moonbeam’) were transplanted in pots (approximately 2.8L volume) containing either the bark-ADDF-perlite or bark-peat-perlite mix. Plants were fertilized with a top dressing of Osmocote 18-6-12 at a rate of 6g per pot. Plants were grown in a glass greenhouse. Plants were overhead irrigated and leachate was collected for nutrient analysis to calculate cumulative quantities of nutrients leached per pot. Growth and

quality of each species was evaluated based on quantitative parameters appropriate its growth habits and a subjective visual evaluation. For brunnera, the number of flower spikes, maximum flower spike length and canopy volume (as described in previous trials) were measured. For coreopsis, dry weight was measured. For Shasta daisy dry weight and number of flowers were measured. For liatris, dry weight, number of flower stems and maximum height were measured. For phlox, dry weight, number of stems and maximum height were measured.
Leachate from each irrigation event was collected, measured gravimetrically and analyzed for NH_4-N, NO_3-N and PO_4-P to calculate the cumulative amount of these nutrients leached.

1.3.9. Unplanted ADDF Leaching

The purpose of this trial was to monitor nutrient release from ADDF. The bark-peat-perlite and bark-ADDF-perlite mixes used for the herbaceous nursery crop trial as well as unammended peat and ADDF were used in this trial. Leachate samples were collected to show nutrient release over time using the methods described in Elliott, 1986 using deionized water as an extractant applied 100ml at a time for the first 8 leaching event and 200ml at a time for the remaining leaching events. Leachate samples were collected on days 1, 4, 6, 9, 16, 18, 21, 23, 27, 29, 37 and 40. All media were stored in an incubator set at 25°C. All extracts were analyzed for pH, EC NH_4-N, NO_3-N and P_2O_5-P concentrations using colorimetric techniques described above.

1.3.10. Statistical Analysis

Statistical Analysis System (SAS institute inc., Cary, South Carolina) was be used to analyze data and data graphics were generated using SigmaPlot (Systat Software, Inc., San Jose, California).

1.4. Results

1.4.1. Media Analysis

Effective water holding capacity (EWHC) and bulk density (D_b) of all ADDF-containing greenhouse mixes were not significantly different from the control mix (Table 1.1). The two coir containing greenhouse mixes had greater container capacities (CCAP) than the control. Bulk density varied little among greenhouse mixes. The coir-ADDF mixes had a pH range of 6.86-7.09 while the other mixes had pH within the optimum range for plant growth. ADDF-containing media had higher EC measurements in SME samples than the control media (1.14mS). The EC of peat-ADDF media ranged from 1.16-1.22mS and the EC of the coir-ADDF media had a range of 1.40-1.96mS. The EC of the ADDF-aggregate mixes were much greater than the other mixes with a range of 2.20-2.60mS.

Table .1. Mean effective water holding capacity (EWHC), container capacity (CCAP) and dry bulk density (D_b)of various greenhouse media. The ratio of mix components is 4:1 for two component mixes and 2:2:1 for three component mixes. Means with different letters are significantly different. Tukey's HSD means separation test was used to find differences in treatments based *p*-value ≤ 0.05.

MIX	EWHC, % volume	CCAP, % volume	D_b, g/cm^3
PEAT-PERL	52.7ab	58.7c	0.106ab
PEAT-ADDF-PERL	52.6ab	61.2bc	0.116a
PEAT-ADDF-PBRH	48.2b	58.0c	0.106ab
COIR-ADDF-PERL	57.1a	66.7a	0.100b
COIR-ADDF-PBRH	49.2b	63.7ab	0.107ab

There were no significant differences in initial physical properties (Table) or pH (5.53 for bark-peat-sand and 5.66 for bark-ADDF-sand) between the nursery mixes. The ADDF-containing nursery mixes had a higher mean EC (1230µS vs. 156µS). At the beginning of the second growing season of the woody nursery crop trial the bark-ADDF-sand mix had significantly lower EWHC and CCAP than the bark-peat-sand mix. Both mixes did, however, have similar D_b upon final measure. There were no significant difference between the mean difference in physical properties between initial and final measures (Table 1.2). The bark-peat-sand mix had significantly more shrinkage in the first season under drip irrigation whereas the bark-ADDF media had significantly more shrinkage upon final measure after approximately 10 weeks of overhead irrigation. Both mixes had the same total amount of shrinkage.

Table 1.2. Mean effective water holding capacity (EWHC), container capacity (CCAP) and dry bulk density (D_b) of two nursery media used for woody nursery crop trial before planting and at the end of the trial. The ratio of mix components is 4:2:1. Means with a * are significantly different based on *p*-value ≤ 0.05.

	EWHC	CCAP	D_b
Initial	% volume	% volume	g/cm
Bark-ADDF-sand	0.476	0.509	0.353
Bark-peat-sand	0.474	0.528	0.335
Significance	ns	ns	ns
End of trial			
Bark-ADDF-sand	0.489	0.698	0.508
Bark-peat-sand	0.591	0.772	0.524
Significance	*	*	ns

Table 1.3. Mean shrinkage of media used in woody nursery crop trials between the beginning of the trial and the end of the first season, between the end of the first season and the end of the trial and total shrinkage. Means with a * are significantly different based on *p*-value ≤ 0.05.

	% of initial volume lost		
Mix	Season 1	Season 2	Total
Bark-ADDF-sand	0.63	10.25	10.87
Bark-peat-sand	5.37	7.00	12.34
Significance	*	*	ns

1.4.2. Bedding Plants and Vegetable Seedlings.

Fresh shoot weights of pansy grown in the control mix and ADDF-perlite mix were significantly greater than those grown in the ADDF-PBRH mix. The mean fresh weight of viola was significantly greater in the ADDF mixes than the control. Fresh weights of petunias grown in the control mix were significantly less than those grown in either of the ADDF mixes and plants grown in the ADDF-perlite mix had greater fresh weights than those grown in the ADDF-PBRH mix. Fresh weights of geranium were not significantly different among treatments. Fresh weights of geranium grown in the control mix were significantly greater than those grown in either ADDF mix and plants grown in the ADDF-perlite mix had greater fresh weight than those grown in the ADDF-PBRH mix. Fresh weights of cucumber were neither significantly different between the two ADDF mixes nor between the ADDF-perlite mix and the control mix but plants grown in the ADDF-PBRH mix had a greater fresh weight than the control (Fig. 1.1).

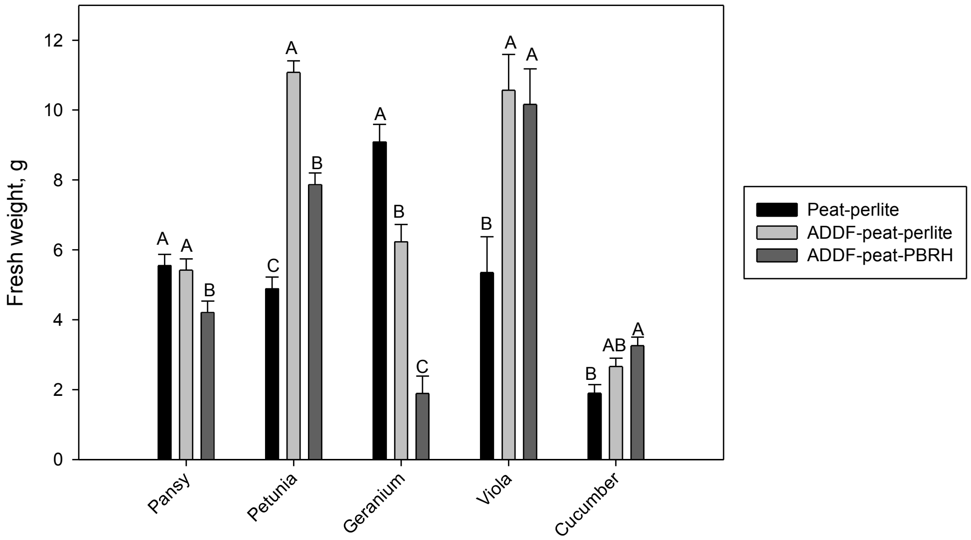


Figure 1.1. Mean fresh weight for bedding plant species grown in media containing either peat and perlite, ADDF and perlite or ADDF and PBRH. Means with different letters are significantly different within species. Tukey's HSD test was used for means separation at $\alpha = 0.05$.

The phosphorus concentrations of plant samples were significantly greater in both ADDF mixes than in the control for all species. (Fig. 1.2). Geranium and cucumber grown in the peat-ADDF-PBRH mix had the greater tissue phosphate than either of the other mixes.

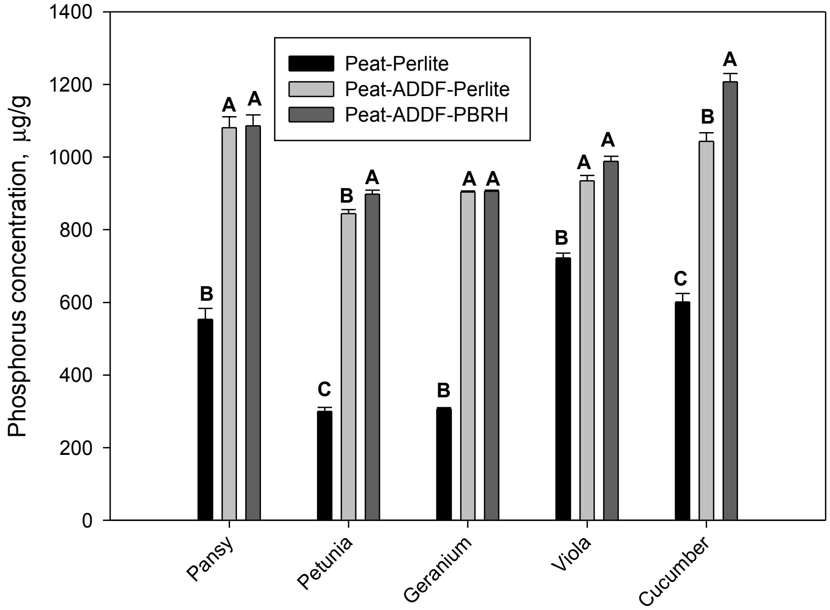


Figure 1.2. Mean leaf tissue phosphorus concentration for bedding plant species grown inmedia containing either peat and perlite, ADDF and perlite or ADDF and PBRH. Means with different letters are significantly different within species. Tukey's HSD test was used for means separation at α=0.05.

Plants grown in ADDF-containing media had significantly greater tissue concentrations of Ca and Mn and significantly lower concentrations of Mg than those grown in the peat-perlite mix for all species. There were no significant differences in tissue K concentrations. There were differences between other nutrient concentrations which varied between species (Table 1.4).

Table 1.4. Mean nutrient concentrations of above ground tissue of four bedding plant species grown in three greenhouse media. Means within species with different letters are significantly different. Tukey's HSD test was used for means separation at α=0.05.

	K	Ca	Mg	Al	B	Cu	Fe	Mn	Mo mg/k	Na	Zn
Pansy	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	g	mg/kg	mg/kg
	2.9										
Peat-perlite	7	0.63b	0.67a	12.5a	186.5	17a	76a	108b	6.9a	352	135.5
ADDF-peat-	3.1		0.44			14.5a					
perlite	8	0.97a	b	18.5a	178	b	58.5b	303a	4.75b	355	134
ADDF-peat-	3.1		0.45								
PBRH	5	0.98a	b	0b	260.5	13b	51.5b	293.5a	1.9c	561	126
Petunia											
	3.0	0.094									
Peat-perlite	7	c	0.82a	65	398.5	19.5	77	46.5b	4.05a	932.5	51b
ADDF-peat-	3.1		0.31								
perlite	6	1.23b	b	72.5	598	14.5	62.5	92a	0.05b	1083	82.5a
ADDF-peat-	3.5		0.34								
PBRH	8	1.39a	b	40	667	16.5	62.5	101.5a	0b	1315	91.5a

Geranium											
Peat-perlite	2.54	0.94b	0.63a	5.5	117b	10.5a	62a	57.5c	3.5a	334.5b	40
ADDF-peat-perlite	2.33	1.16a	0.21b	3	104b	7b	39b	133.5b	0.45b	275b	48.5
ADDF-peat-PBRH	2.37	1.22a	0.25b	5.5	211.5a	8b	47b	177.5a	0.3b	542.5a	48
Viola											
Peat-perlite	3.17	0.57b	0.57	34.5a	346.5	18	84.5	147.5b	2.1	534.5	119.5
ADDF-peat-perlite	3.63	0.94a	0.51	13.5b	374.5	16.5	81	216a	1.55	706	145
ADDF-peat-PBRH	3.77	0.93a	0.51	7b	400.5	17	80.5	235.5a	0.9	665	137.5

Overall performance was varied. In some crops, such as viola, plants performed much better in the ADDF mixes than in the control mix but in some other crops the control plants were larger and were a healthier dark green than plants grown in the ADDF mixes (Fig. 1.3).

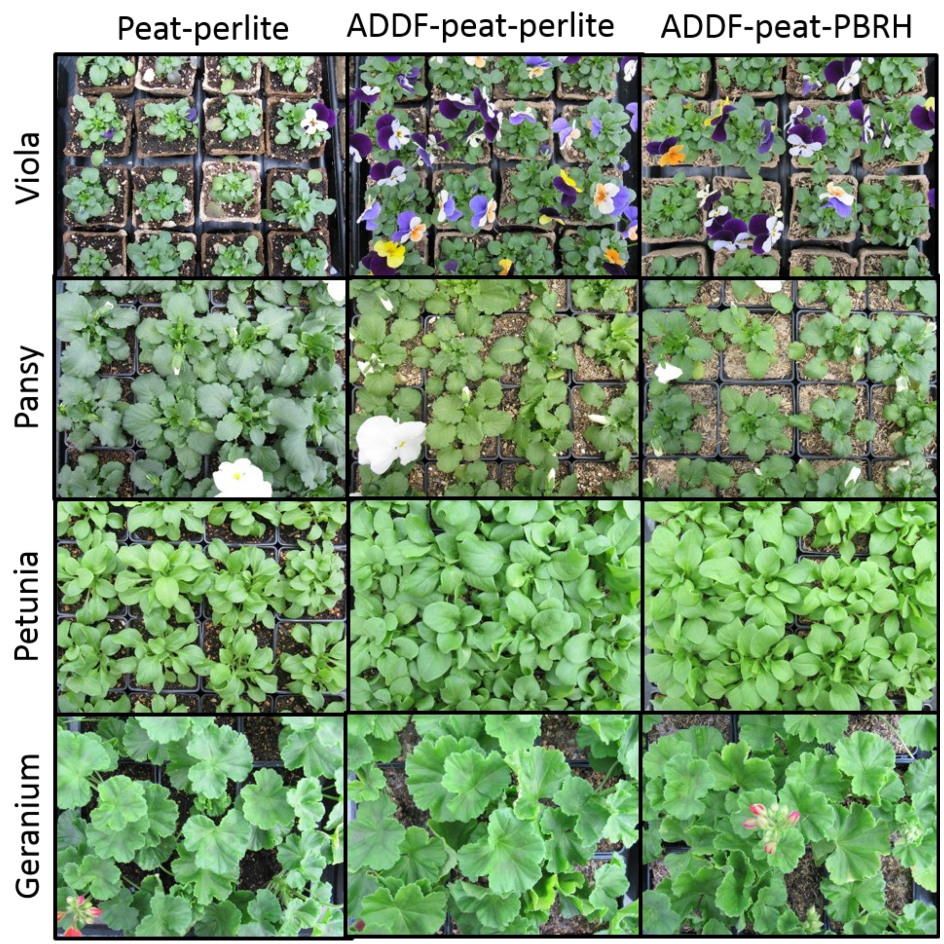


Figure 1.3. Bedding plants grown in media containing peat-perlite, ADDF-peat-perlite or ADDF-peat-PBRH

1.4.3. Garden Chrysanthemum.

Final plant fresh weights volumes and maturity were greatest for plants in the control mix. Fresh weights were greater in plants grown in perlite-containing mixes than in PBRH-containing mixes (Table 1.5). Plants grown in mixes without PBRH were of marketable size and quality (Fig. 4).

C PP PR CP CR

Figure 1.4. Chrysanthemum 'Hankie Yellow' grown in mixes with a 2:2:1 ratio of the following; peat:ADDF:perlite (PP), peat:ADDF:PBRH (PR), coir:ADDF:perlite (CP), coir:ADDF:PBRH (CR) and fafard 1-P, a peat-lite control mix (C).

1.4.4. Cyclamen.

All peat-containing mixes produced saleable plants of a similar quality (Fig. 1.5) and size (Table 1.5). Both coir-containing mixes produced smaller plants of inferior quality.

C PP PR CP CR

Figure 1.5. Cyclamen 'Silver Heart' (left) and 'Winfall' (right) grown in mixes with a 2:2:1 ratio of the following; peat:ADDF:perlite (PP), peat:ADDF:PBRH (PR), coir:ADDF:perlite (CP), coir:ADDF:PBRH (CR) and fafard 1-P, a peat-lite control mix (C).

Table 1.5. Mean canopy volumes, fresh shoot weight and maturity of garden mums and mean canopy volumes cyclamen grown in five SPM with a 2:2:1 ratio of the following; peat:ADDF:perlite (PP), peat:ADDF:PBRH (PR), coir:ADDF:perlite (CP), coir:ADDF:PBRH (CR) and fafard 1-P, a peat-lite control mix. Means with different letters are significantly different. Tukey's HSD means separation test was used to find differences in treatments based *p*-value ≤ 0.05.

	Garden Chrysanthemum			Cyclamen
Mix	Volume, dm^3	Fresh weight, g	Maturity rating	Volume, cm3
Peat-perlite	15.46a	611a	2.5a	1103a
Peat-ADDF-perlite	13.34b	537.44b	2.56a	925a
Peat-ADDF-PBRH	9.91d	460.44c	1.89b	837a
Coir-ADDF-perlite	11.6c	511.67b	2.56a	467b
Coir-ADDF-PBRH	9.20d	402.22d	2.06b	226b

1.4.5. Poinsettia.

Plants grown in the ADDF mix were significantly larger (Table 1.6) than those grown in the peat-based mix. Poinsettias grown in the ADDF mix also had higher leaf tissue concentrations of N, P, K and Ca. The plants grown in the peat based mix, however, had higher leaf tissue concentrations of Mn, Na and Zn (Table 1.7)

Table 1.6. Mean fresh weight, height and phosphorus concentration of poinsettias grown in ADDF or peat-containing media. Parameters with a * are significantly different based on *p*-value ≤ 0.05.

Mix	Fresh weight, g	Dry weight, g	Height, mm
Peat-perlite	117	15.5	177
ADDF-peat--perlite	133	18.0	192
Significance	*	*	*

Table 1.7. Mean leaf tissue nutrient concentrations of poinsettia grown in two greenhouse media. Nutrients with * have significantly concentrations different means between plants grown in the two mixes at *p*-value ≤ 0.05.

Mix	N %	P %	K %	Ca %	Mg %	Al mg/kg	B mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Na %	Zn mg/kg
Peat-perlite	3.5	0.2	2.5	0.6	0.5	4.4	26.7	10.6	217.9	81.9	0.1	0.2	50.8

ADDF-peat-perl	3.9	7 0.3 4	2.3	0.5	0.5	1.1	26.7	12.2	140.8	108.1	0.0	0.3	86.2
Significance	*	*	*	*	ns	ns	ns	ns	ns	*	ns	*	*

PourThru samples from pots containing ADDF mixes had significantly higher P_2O_5-P concentrations for approximately five weeks and P_2O_5-P concentrations began to rise again toward the end of the trial (Fig. 1.6).

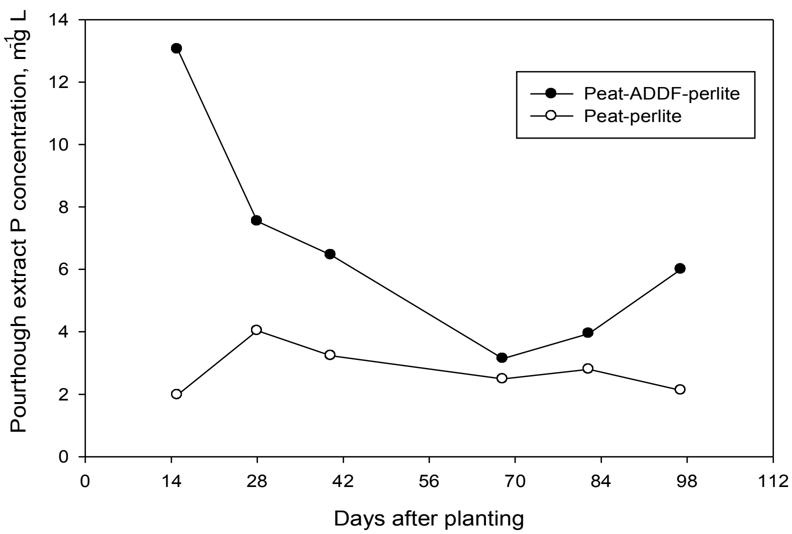


Figure 1.6. Mean phosphorus concentration in PourThru extracts from poinsettia crop grown in peat-perlite and ADDF-peat-perlite media.

Plants grown in the ADDF mix were also visually larger and denser (Fig. 1.7).

Peat-perlite

Peat-ADDF-perlite

Figure 1.7. Poinsettias grown in peat-perlite (left) and peat-ADDF-perlite (right) media.

1.4.6. Woody Nursery Crops

Measurements taken at the end of the first season of growth after transplanting show no differences in size, stem caliper or number of stems between button bush and silky dogwood grown in the peat mix and ADDF mix (Fig. 1.8). Analysis of PourThru samples show elevated levels of orthophosphate in the ADDF mix for approximately 8 weeks after planting (Fig. 1.9).

At the end of the first growing season there was 0-13% media shrinkage with no significant difference between the two nursery mixes (Table 1.3). Upon harvest after leafing out in the second season there were no differences in height, maximum caliper, dry weight, new shoots (Fig. 1.10) or visual appearance (Fig 1.11) between plants grown in the two mixes.

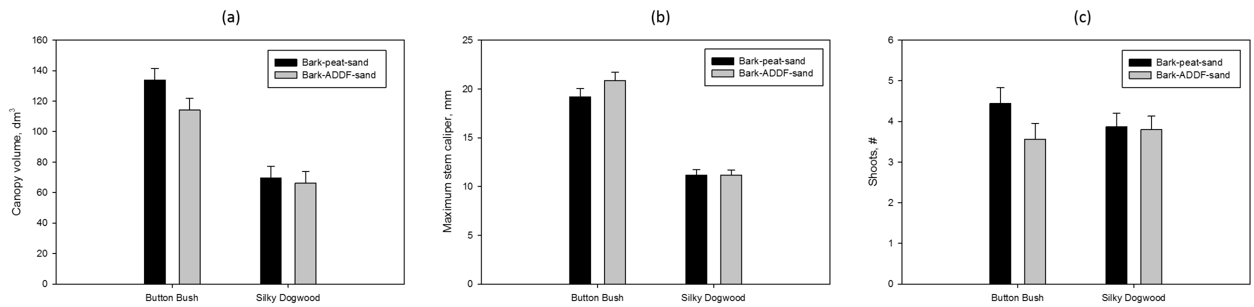


Figure 1.8. Mean volume, number of shoots and largest shoot caliper of button bush and silky dogwood after one season of growth in either peat- or ADDF-containing media in a ratio of 4 bark: 2 peat:1 sand or 4:bark:2 ADDF: 1 sand. No significant differences were found based on p-value ≤ 0.05.

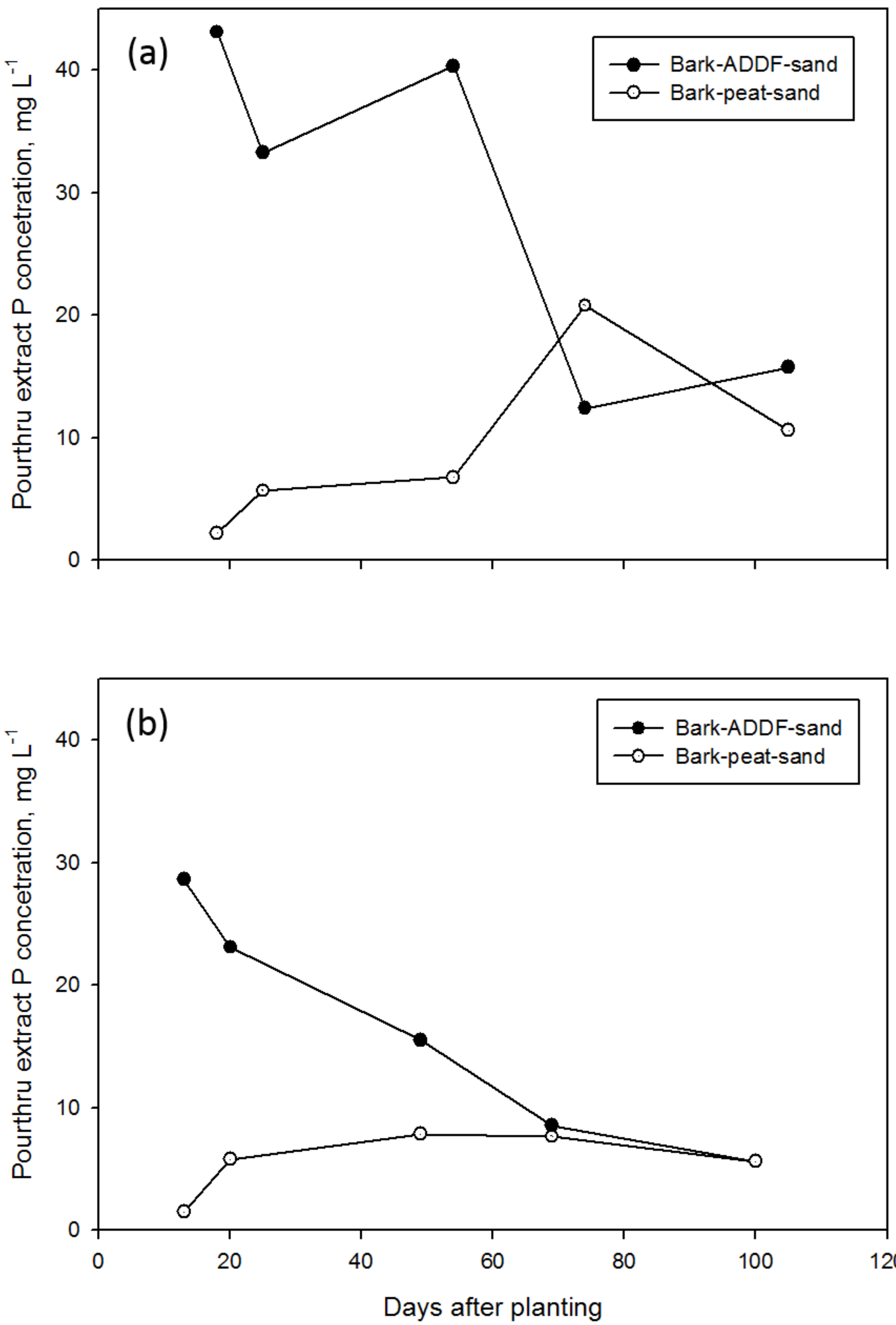


Figure 1.9. Mean phosphorus concentrations in PourThru samples from button bush (a) and silky dogwood (b) through one growing season.

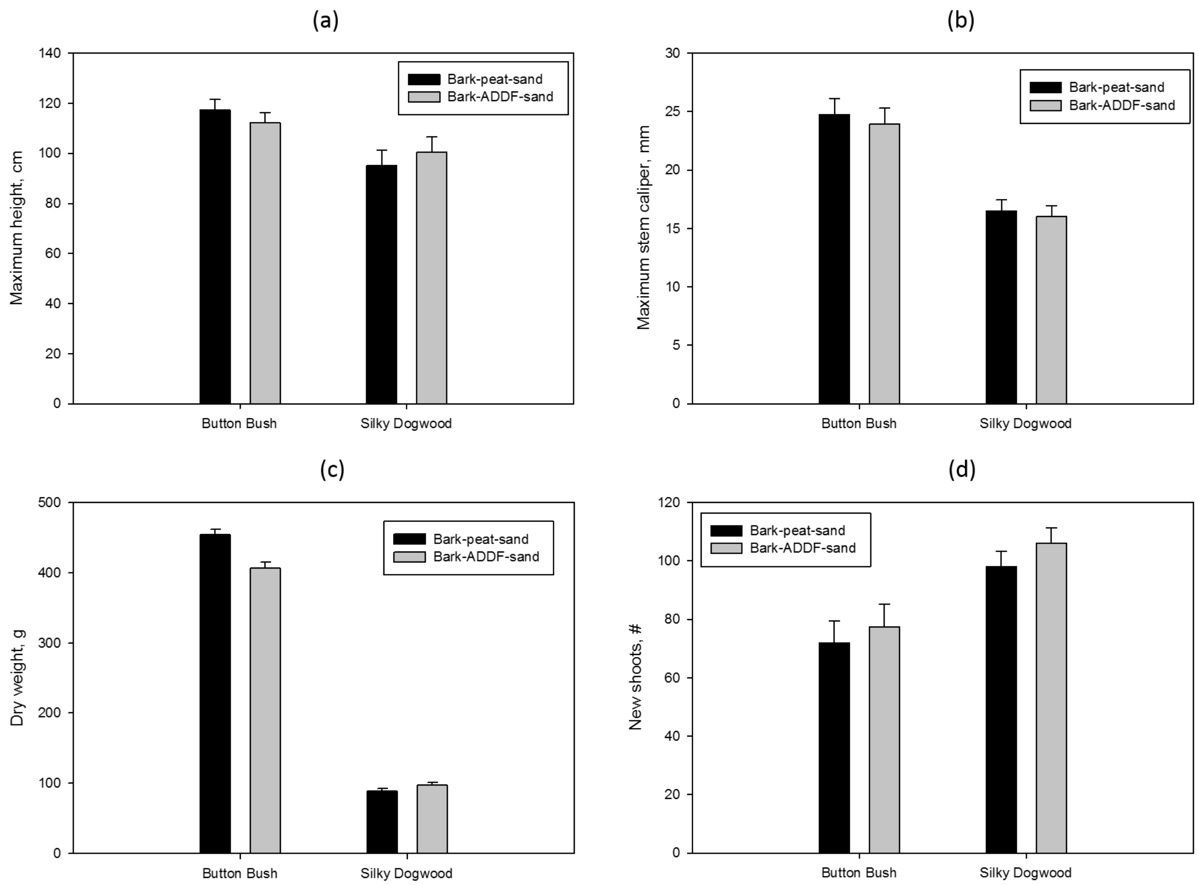


Figure 1.10. Mean maximum height (a), maximum stem caliper (b), dry weight (c) and number of new shoots (d) of button bush and silky dogwood after leafing out in spring of second season growing in bark-peat-sand or bark-ADDF-sand nursery media. No significant differences were found based on p-value ≤ 0.05.

Figure 1.11. Randomly selected representatives of button bush (left) and silky dogwood (right) after leafing out in second season growing in bark-ADDF-sand (top) or bark-peat-sand (bottom) nursery mixes

1.4.7. Woody Cuttings

At the end of the first growing season there were no noticeable differences between plants in the two mixes. At the beginning of the second season both ninebark and viburnum grown in the bark-ADDF-sand mix appeared to break from dormancy more quickly, vigorously and with darker foliage (Figs. 1.13 & 1.14). The plants grown in the bark-ADDF-sand mix were also significantly taller than the plants grown in bark-peat-sand mix. Ninebark grown in the bark-ADDF-mix had a greater dry weight but there was no difference in dry weight between viburnum grown in either mix (Fig. 1.12).

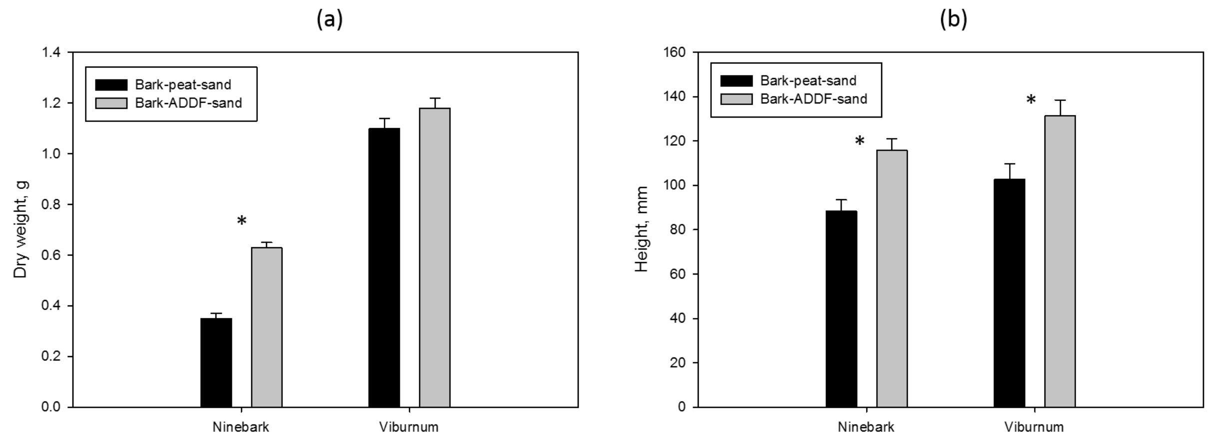


Figure 1.12. Mean above ground dry weight (a) and height (b) of rooted cutting of ninebark and cranberry bush viburnum after leafing out in second season growing in bark-ADDF-sand (top) or bark-peat-sand (bottom) nursery mixes. Bars with a * have significant differences between media at p-value ≤ 0.05.

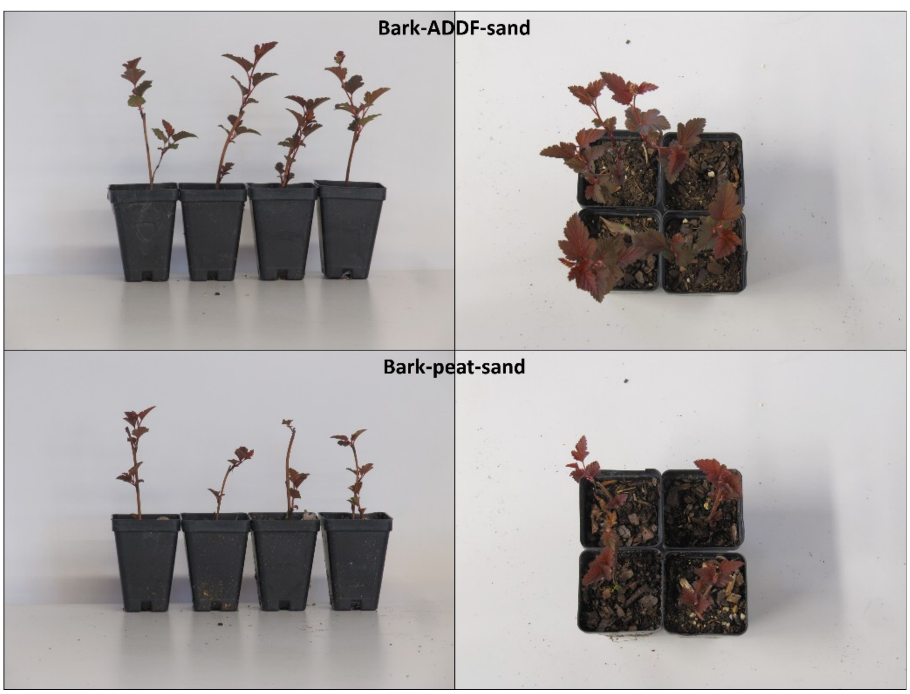


Figure 13. Randomly selected representatives of ninebark after leafing out in second season growing in bark-ADDF-sand (top) or bark-peat-sand (bottom) nursery mixes

Figure 14. Randomly selected representatives of cranberry bush viburnum after leafing out in second season growing in bark-ADDF-sand (top) or bark-peat-sand (bottom) nursery mixes

1.4.8. Herbaceous Nursery Crops

Of all plant growth parameters measured, the only significant differences between plants grown in bark-peat-perlite and bark-ADDF-perlite were greater fresh and dry weights in Shasta daisy grown in the bark-ADDf-perlite mix (Tables 1.8-1.12). While no differences were found in measured parameters there were some visible differences in plant growth and development between the two treatments in some species (Fig 1.15). Coreopsis (Fig 1.15.b) grown in the bark-ADDF-perlite mix were slightly chlorotic and less dense. Brunnera (Fig. 1.15.a) grown in the bark-ADDF-perlite mix had slightly chlorotic leaf margins and a deeper blue flower color than those grown in the bark-peat-perlite mix. Overall, plant growth in the bark-ADDF-perlite mix was more variable than in the control mix with many plants in the bark-ADDF-perlite mix growing to an acceptable size and quality but others being severely stunted.

A much greater amount of phosphate was leached from pots containing the bark-ADDF-perlite mix and continued to be released through the growing season of all crops tested (Figs. 1.16-1.20)

Table 1.8. Mean number of flower spikes, maximum flower spike length and canopy volume of brunnera grown in two nursery mixes. No significant differences were found based on p-value ≤ 0.05.

Mix	Flower spikes	Maximum flower spike length, mm	Volume, ml
Bark-ADDF-sand	2.4	171.96	1016.86
Bark-peat-sand	1.8	170.72	791.37

Table 1.9. Mean dry weight of coreopsis grown in two nursery mixes. No significant differences were found based on p-value ≤ 0.05.

Mix	Dry weight, g
Bark-ADDF-sand	8.81
Bark-peat-sand	9.24

Table 1.10. Mean dry weight and flower count of Shasta daisy grown in two nursery mixes. Parameters with a * are significant at p-value ≤0.05.

Mix	Dry	Flowers

	weight, g*	
Bark-ADDF-sand	4.29	1.75
Bark-peat-sand	2.74	1.33

Table 1.11. Mean dry weight, flower stem count and maximum height of liatris grown in two nursery mixes. No significant differences were found based on p-value ≤ 0.05.

Mix	Dry weight, g	Flower stems	Height, cm
Bark-ADDF-sand	20.81	5.08	28
Bark-peat-sand	18.6	6.42	29.5

Table 1.12. Mean dry weight, stem count and maximum height of phlox grown in two nursery mixes. No significant differences were found based on p-value ≤ 0.05.

Mix	Dry weight, g	Stems	Height, cm
Bark-ADDF-sand	7.74	2.67	29.17
Bark-peat-sand	6.9	3.25	29

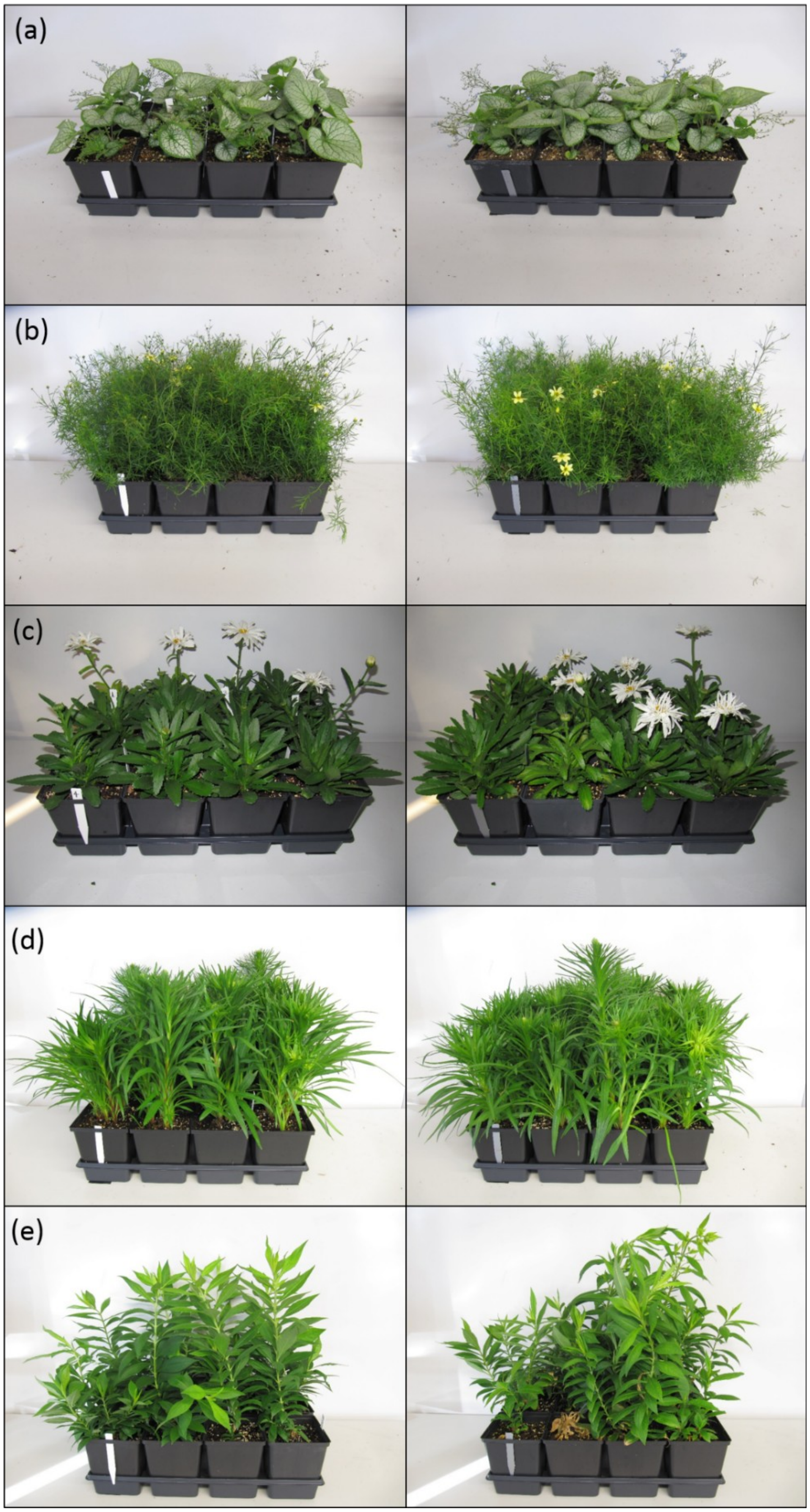


Figure 1.15. Brunnera (a), coreopsis (b), Shasta daisy (c), liatris (d) and phlox (e) grown in bark-peat-perlite (left) or bark-ADDF-perlite (right) nursery mixes.

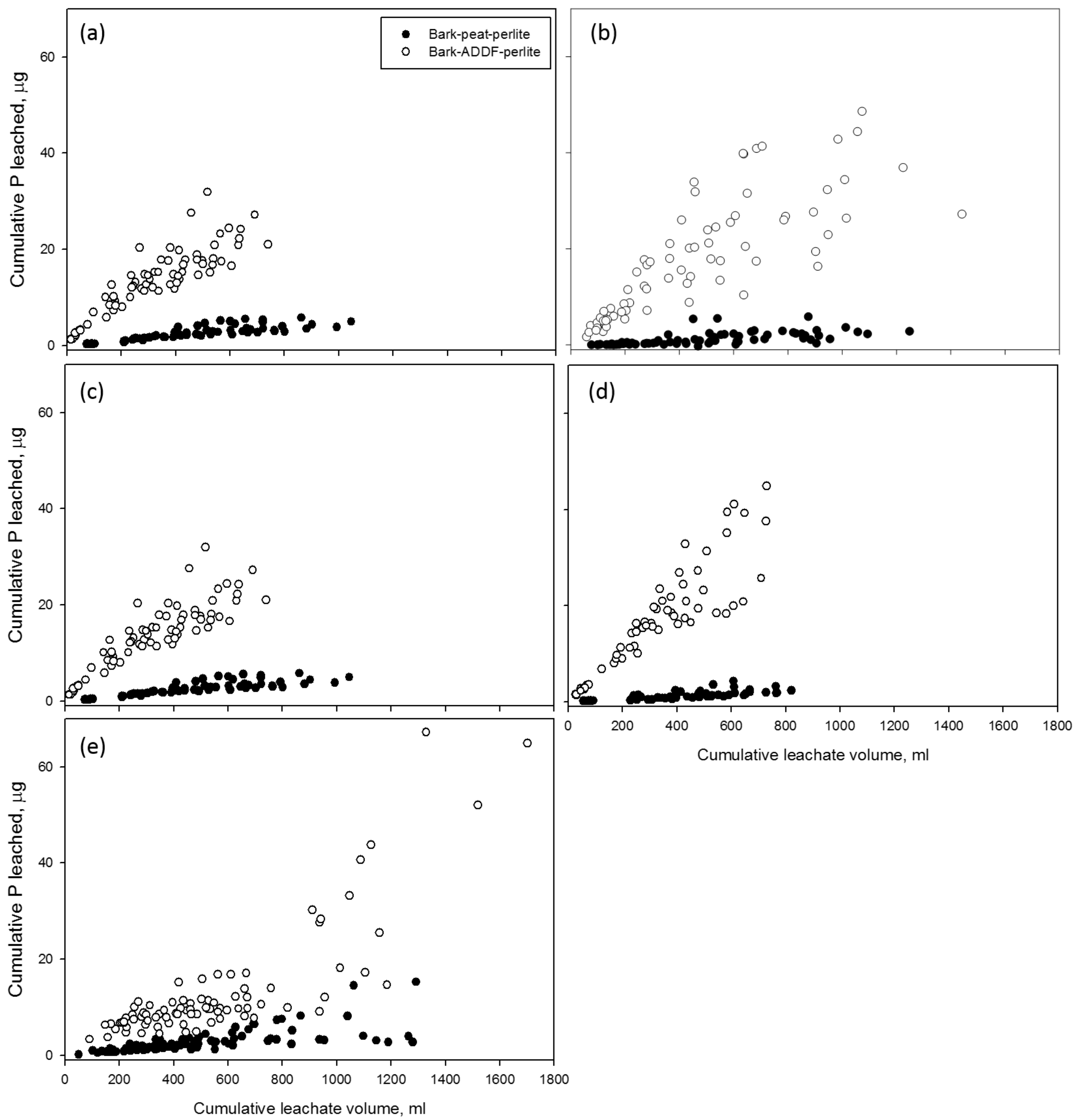


Figure 1.16. Cumulative phosphorus leached from brunnera (a), coreopsis (b), Shasta daisy (c), liatris (d) and phlox (e) pots containing two nursery mixes

Unplanted ADDF Leaching

Phosphate was continually released from the raw ADDF and the bark-ADDF-perlite mix throughout the trial and only began to plateau at the end. Peat and the bark-peat-perlite mix released negligible amounts of phosphate (Fig 1.21).

Virtually all nitrate was released after the fourth leaching event. The raw ADDF released far more nitrate than the bark-ADDF-perlite. The bark-ADDF-perlite mix is slightly less than 30% ADDF but only releases approximately 17% of the nitrate released from the raw ADDF. This suggests that mixing ADDF with bark immobilizes nitrogen and reduces nitrate leaching. Peat and the bark-peat-perlite mix released negligible amounts of nitrate (Fig 1.22).

Ammonium was slowly released by all mixes with the ADDF mixes releasing the greatest quantities (Fig 1.23).

There was an initial dip in pH followed by a rise and a leveling off (Fig 1.24). Most soluble salts were leached in the first few leaching events (Fig 1.25). The rapid release of nitrate and soluble salts in ADDF paired with the steady release of phosphate suggest ADDF has a large store of adsorbed labile phosphate.

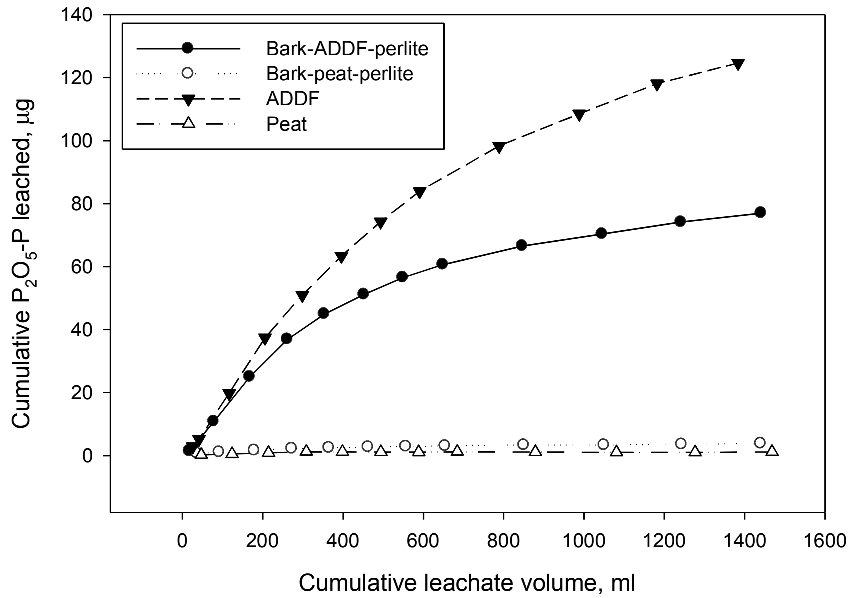


Figure 1.20. Mean cumulative phosphate phosphorus leached from unplanted pots containing two nursery mixes, raw ADDF and peat.

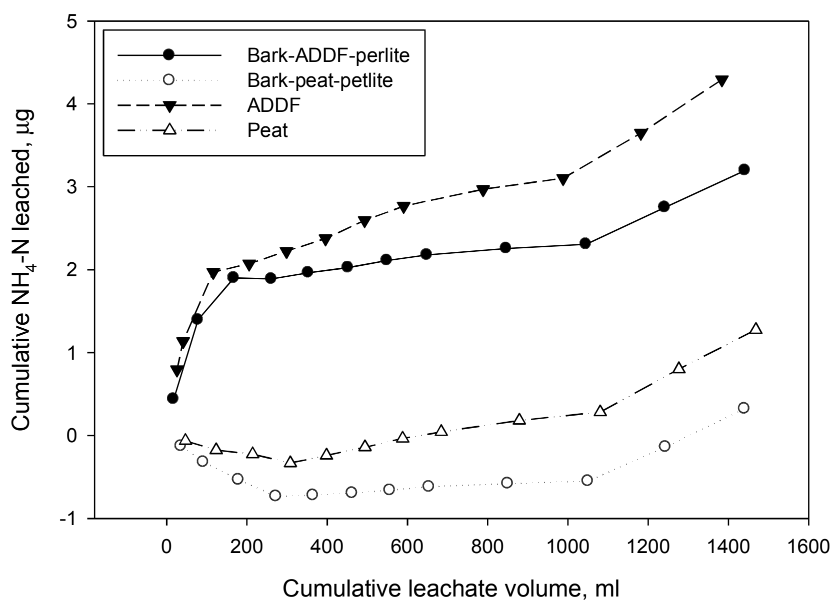


Figure 1.21. Mean cumulative ammonium nitrogen leached from unplanted pots containing two nursery mixes, raw ADDF and peat.

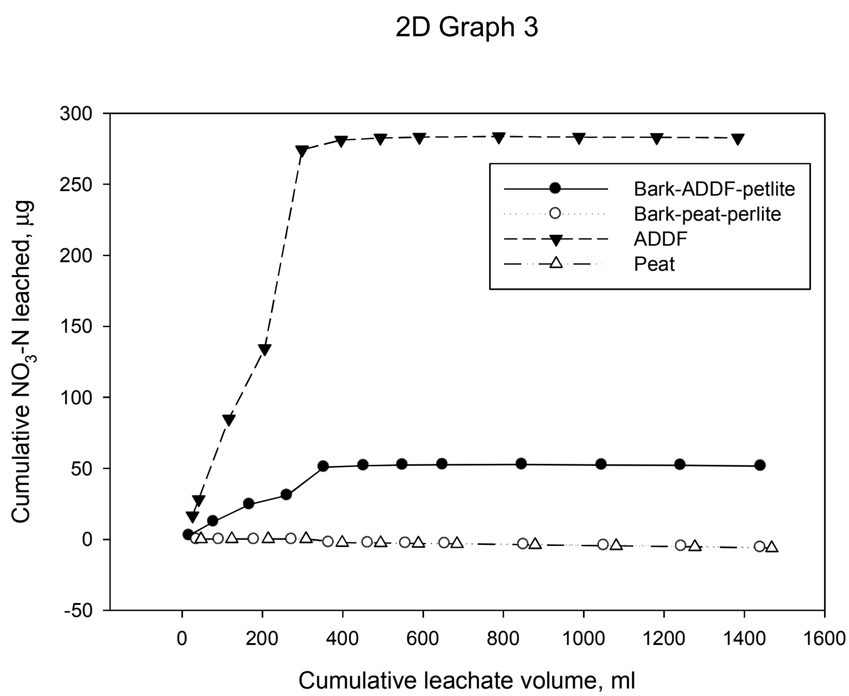


Figure 1.22. Mean cumulative nitrate nitrogen leached from unplanted pots containing two nursery mixes, raw ADDF and peat.

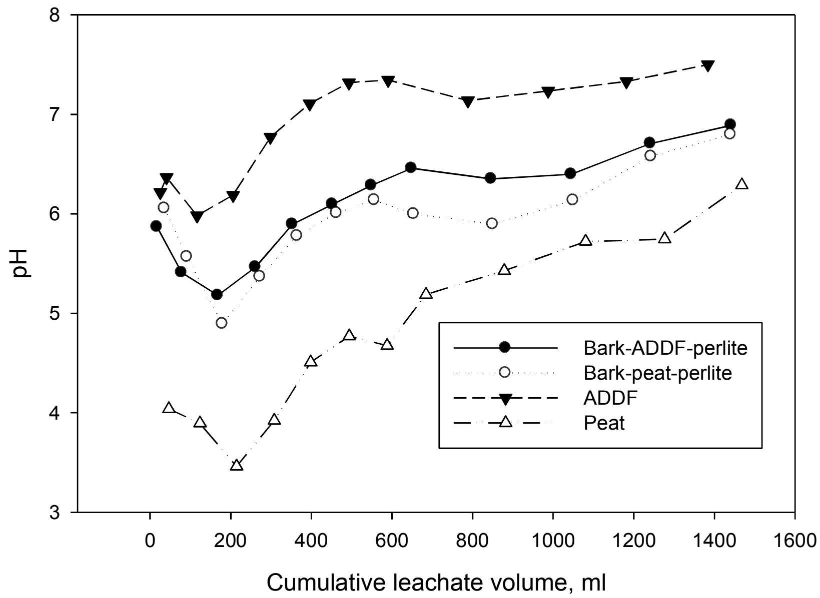


Figure 1.23. Mean leachate pH from unplanted pots containing two nursery mixes, raw ADDF and peat over time.

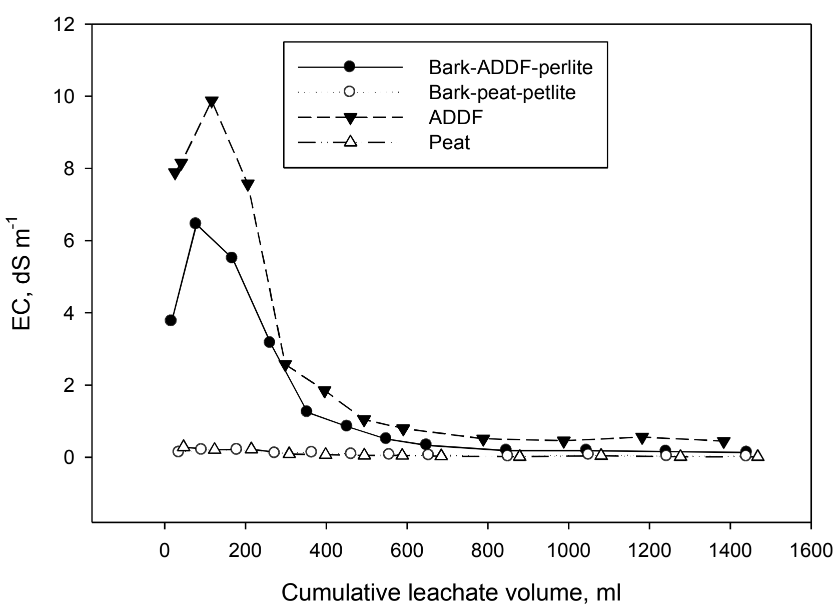


Figure 1.24. Mean leachate EC from unplanted pots containing two nursery mixes, raw ADDF and peat over time.

1.5. Discussion

ADDF can be used as a partial replacement for peat in SPM for a variety of floriculture crops and as a complete replacement for peat in nursery mixes. Irrigation, fertilization and pH management must be considered carefully when using an ADDF as a media component. When other alternative media components, like coir and PBRH were used in concert with ADDF results were less favorable. Generally, the more a mix deviated from a standard peat-based, the more likely it was to have unfavorable results. For example, the coir-ADDF-PBRH mix that was used in the chrysanthemum and cyclamen trials contained none of the same media components as the control and did not yield any favorable results.

Much of the variability in growth response appeared to be related to nutrient availability which, in turn, was likely related to pH. Nutrient availability is usually more dramatically affected by pH in SPM than in mineral soils (Peterson, 1982) so pH management is especially important in soilless culture. In the greenhouse mixes ADDF only replaced half the peat in the mix and the alkalinity of the ADDF and acidity of peat reacted to make a media with an appropriate pH for plant growth (5.4-6.0) (Dole and Wilkins, 1999).

Amending ADDF-containing greenhouse mixes with gypsum was effective in supplying plants with Ca while not affecting the pH but did not supply plants with the Mg normally supplied by dolomitic lime. Leaf tissue analysis revealed that both petunia and geranium grown in ADDF-containing mixes were on the cusp of Mg deficiencies (Dole and Wilkins, 1999). A magnesium source should be added to the fertilization regime of ADDF-containing mixes in an appropriate ratio with gypsum to supply the required amount and ratio of Ca and Mg without greatly altering the pH.

Results from all these trials show that ADDF is a significant source of plant available phosphorus. All plants grown in ADDF-containing mixes had elevated tissue P concentrations and all aqueous extracts (SME and PourThru) from ADDF mixes had higher concentrations of phosphate than peat-based mixes. There were higher concentrations of P in leachate and PourThru samples throughout the growing cycles of all trials. The continued release of P may be from the dissolution of calcium phosphate minerals which are often found in dairy manure and dissolve at pH below 7 (Shober et al., 2010). Measures should be taken to limit P leaching from ADDF containing mixes, such as using irrigation systems with little or no leaching, adjusting to low P fertilization regimes or formulating media with pH closer to neutral to slow dissolution of calcium phosphate minerals. Certain media amendments, such as dried alum sludge have been shown to greatly reduce P leaching from media containing organic P sources without adversely effecting plant growth (Bugbee & Elliott, 1999).

Shober et al. (2011) reported that leachate from CowPeat contained a only negligible amount of reactive nitrogen, often even less than peat based mixes. The leaching trials conducted for this research showed much greater quantities of reactive nitrogen being leached from ADDF-containing mixes than from mixes without ADDF. The differences in the nitrogen leaching between Shober et al. (2011) and this research could be due to regional differences in dairy manure (Florida vs Connecticut) or in differences between how aerobic (CowPeat) and anaerobic (ADDF) processing of dairy manure affects the nitrogen forms in the processed material. Nitrogen leaching was not a concern in the use of CowPeat but may be for the use of ADDF.

Nutrients leached from a mix do not necessarily equal the sum of nutrients that leach from the individual components that are in the mix. There are complex interactions between media components which can make nutrients more or less susceptible to leaching. This can be seen in the unplanted leaching trial of nursery mixes, peat and raw ADDF. Mixing ADDF with bark in the nursery mix appeared to reduce the amount of nitrate leached. Bugbee and Elliott (1998) showed that bark and other media components could reduce the amount of P leached from a compost-based mix when compared with peat. In the same study, a compost-based mix with zeolite or vermiculite leached greater quantities of P when compared to the bark mix. A better understanding how ADDF interacts with other media components will allow mixes to be formulated which minimize leached while providing a sufficient supply of plant available nutrition.

In the nursery mixes peat made up a much smaller proportion of the mix than in greenhouse mixes (slightly less than 30% vs. 80%) so ADDF was an acceptable replacement for all the peat in the mix rather than only replacing 50% of the peat. All nursery crops grown in ADDF-containing mixes grew to a similar or better size and quality than those grown in the peat-based nursery mixes. This may have been due to the smaller proportion of peat being replaced or that nursery crops are generally more robust than greenhouse and floriculture crops and may have been better able to tolerate suboptimal root zone conditions. Despite the smaller proportion of peat in nursery mixes, nursery crops are grown in containers with much larger volumes, which require greater volumes of media than greenhouse crops so using ADDF as a replacement for peat in nursery mixes could still significantly reduce demand for peat.

While the growth and quality of nursery crops ADDF containing mixes were statistically similar to those grown in the peat-based control mix, growth responses of plants in the ADDF mix were generally more variable. It is important for a growing mix to produce consistent results. so while the ADDF mixes yielded acceptable means, the variable growth in some species may be unacceptable in practical applications. This variability may have been due to management decisions or the ADDF itself.

In these trials, management decisions were based on established cultural recommendations for peat-based control mixes. In many cases, irrigation management that was optimal for the control mix was less than optimal for other treatments. This was illustrated by the media analyses at before, during and after the woody nursery crop trial. The ADDF mix had less shrinkage than the control during the first season when pots were under drip irrigation but experienced much more shrinkage during the second season under overhead irrigation. Many of the crops that were exclusively overhead irrigated, like phlox, coreopsis and cranberry bush viburnum had dead or severely stunted individuals. All of this suggests overhead irrigation may lead to accelerated compaction of ADDF mixes. Through observations during trials and results from the bedding plant, chrysanthemum and cyclamen trials it appears that PBRH do not conduct water as well as perlite and do not work as well with irrigation systems that require good hydraulic conductivity such as subirrigation and, especially drip irrigation. Better results may be produced with individualized management decisions based on differences in mixes. Additionally, ADDF is a significant source of phosphate and nitrate and fertilization regimes should be adjusted accordingly.

Some of the variability in growth response of plants grown in ADDF-containing mixes may have been due to heterogeny of the ADDF itself. The ADDF used in this project was processed to be used in the production of biodegradable “Cowpots™” rather than for use in potting media. An ADDF product that produces more consistent results may be obtainable from processing with a media component as a goal as is done with other anaerobically digested organic media components such as Magic Dirt™ or EcoTek®.

There may also be variability in ADDF on a larger scale. Dairy feed can vary from region to region and seasonally so the feedstock used to produce ADDF likely varies equally. Regional variability in dairy manure may have contributed to discrepancies between the results of this research and the results of research using a dairy manure product in Florida (Shober et al., 2011). However, similarities in results of chemical and physical analysis of ADDF and ADDF-containing mixes between MacConnell and Collins (2009) in Washington and these trails in Connecticut demonstrate that ADDF can be consistent from region to region.

Differences in climate have been show to influence the nutrient availability in manure. Growing degree days have been shown to be useful in predicting nitrogen availability from manure (Griffin and Honeycutt, 2000). Special consideration must be given to any potential variability in ADDF.

As with other alternative media components more research is needed to establish the best ways to manage ADDF in media and to process ADDF into a consistent horticultural material. Apart from establishing best practices for ADDF, it is an acceptable replacement for peat in a wide variety of media and for a diversity of horticultural crops.

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Using Anaerobically Digested Dairy Fiber in Soilless Potting Mixes

George Elliott, Ph.D.

Anaerobically digested dairy fiber (ADDF) can be used as an ingredient in soilless potting mixes for greenhouse or nursery production. However, as with all potting mix components, careful management is required for success.

First, it's important to have a consistent source of ADDF, in terms of both quantity and quality. ADDF is produced from a variable feedstock by a biological process that is has to be closely regulated for uniform results. Some variability has to be expected; don't guess, test! A lab specializing in soilless media testing can provide information on pH, soluble salts, plant nutrients and non-nutrient elements.

One characteristic of ADDF that has to be dealt with is high pH. The recommended pH for soilless potting mixes is about 5.6 to 6.5, but the pH of ADDF is typically about 8.5. Two methods can be used to neutralize the alkalinity from ADDF: first, ADDF can be amended with elemental sulfur, and second, it can be blended with acidic bulk materials. Sulfur addition at about 1.5 to 3 lbs/yd^3 (2 to 6 kg /m^3) will reduce the pH of ADDF to 6 or lower. Neutralization with sulfur depends on microbial conversion to sulfate, which can take up to 2 weeks. The reaction of ADDF with acidic materials such as peat or composted softwood bark is rapid and will yield a desirable pH. The pH of the mix should be monitored on a regular basis. Conversion of ammonium to nitrate can result in a rapid drop in pH.

ADDF contains plant nutrients, notably phosphorus and nitrogen (mostly ammoniacal). Therefore, supplemental fertilizer should be formulated with a low proportion of phosphorus (*e.g.*, 19-2-19), and should be applied at a relatively low concentration (*e.g.*, 100 to 125 ppm N).

Water retention and aeration in ADDF is similar to peat, and irrigation practices for ADDF mixes are essentially the same as for their conventional counterparts. Growers should be aware of the need to carefully monitor irrigation practices when switching to any new mix. Because the nutrients in ADDF are soluble, they can be leached from potting mix. To avoid this, irrigation management should aim for zero or minimal leaching. Subirrigation or regulated drip irrigation would be preferred methods.

ADDF can be used as a partial or complete substitute for peat in combination with other bulk components such as composted bark, coir, perlite and parboiled rice hulls. Following are two recipes for ADDF potting mixes that have been used in greenhouse and nursery production, respectively:

A. 40% PEAT: 40% ADDF: 20% PERLITE
   add gypsum at about 2.5 lbs/yd3 (4 kg/m^3)

B. 50% BARK: 33% ADDF: 17% SAND or PERLITE
   add gypsum at about 2.5 lbs/yd3 (4 kg/m^3)
   sand for outdoor production in large pots where a higher bulk density is desirable; perlite for small pots and protected cultivation

ADDF PRESENTATION

Anaerobically Digested Dairy Fiber as a Substitute for Peat in Potting Mixes

George Elliott, Ph.D.

Soilless Potting Mixes

- Peat-based mixes
  - Physical and chemical properties suitable for use in containers
  - Peat relatively consistent
  - Easy to handle
  - Reduced plant pathogen and weed risks

Peat: Issues

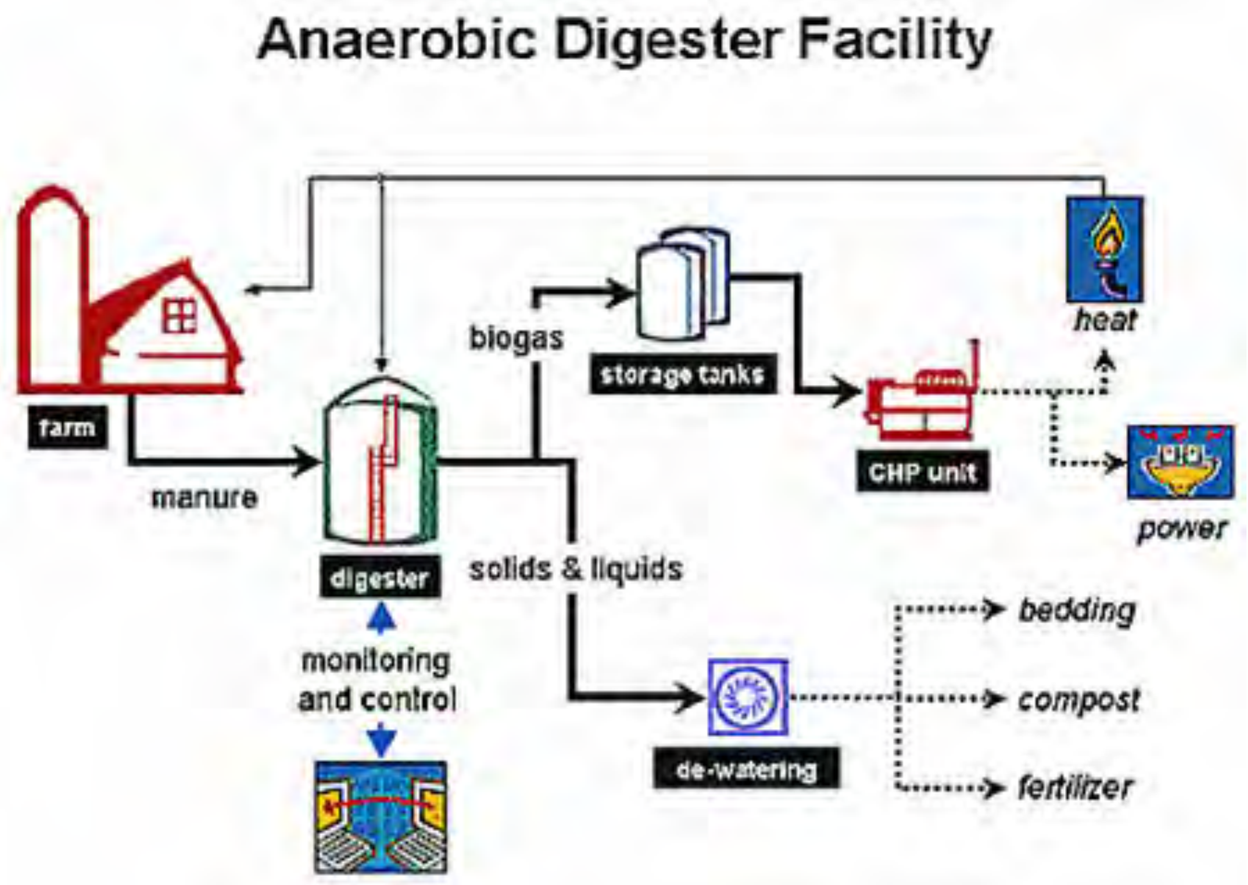
Environmental Degradation

Public pressure

www.theecologist.org

Anaerobically Digested Dairy Fiber: A Potential Peat Substitute

- Renewable byproduct
- Potential revenue for dairy farmers
- Previous research at Washington State Univ. & Univ. Wisconsin



smallfarms.cornell.edu

ADDF: A Potential Peat Substitute

- Physical characteristics similar to peat
- Commercial products, *e.g.,* Magic Dirt™, CowPots™

Objectives

- To evaluate ADDF as a substitute for peat in soilless potting mixes (SPM) for greenhouse and nursery crop production
- To evaluate nutrient availability and leaching potential in ADDF media over time.
- To evaluate physical characteristics of ADDF-containing SPM over time

Grower trials

- Grower Direct Farms, Somers, CT
  - Garden mums
  - 40% ADDF: 40% peat: 20% perlite
  - 8” pans
- Freund Family Farm, East Canaan, CT
  - source of ADDF
  - flowering annuals
  - grown in CowPots™
  - 40% ADDF: 40% peat: 20% perlite vs commercial mix (Fafard 1P)

Grower Direct

August 7

October 26

Freund Farm

UCONN trials

- Graduate student M.S. research
- Physical and chemical properties
- Crop trials
- Additional support from Sustainable Agriculture Research & Extension program

Media physical and chemical characteristics

- Physical
  - Water retention
  - Bulk Density (Db) = dry mass / volume
  - Shrinkage = loss of volume as proportion of initial volume
- Chemical
  - pH; important for nutrient availability
  - Electrical conductivity (EC); soluble salts
  - Saturated media extracts

Media formulations

	Bedding Plants	Garden Chrysanthemum	Cyclamen	Poinsettia	Woody Nursery Crops	Woody Cuttings	Herbaceous perennials
4:1 Peat-perlite	X	X	X	X			
2:2:1 Peat-ADDF-perlite	X	X	X	X			
2:2:1 Peat-ADDF-PBRH	X	X	X				
2:2:1 Coir-ADDF-perlite		X	X				
2:2:1 Coir-ADDF-PBRH		X	X				
4:2:1 Bark-peat-sand					X	X	
4:2:1 Bark-ADDF-sand					X	X	
4:2:1 Bark-peat-perlite							X
4:2:1 Bark-ADDF-perlite							X

Greenhouse Media

MIX	Effective water retention % volume	Container capacity % volume	Bulk density g/cm3	pH	Electrical conductivity mS/cm
peat-perlite	52.7ab	58.7c	0.106ab	5.96	1.14
peat-ADDF-perlite	52.6ab	61.2bc	0.116a	6.56	1.16
peat-ADDF-PBRH	48.2b	58.0c	0.106ab	6.55	1.22
coir-ADDF-perlite	57.1a	66.7a	0.100b	7.09	1.40
coir-ADDF-PBRH	49.2b	63.7ab	0.107ab	6.86	1.96
ADDF-perlite	47.9b	61.4bc	0.117a	7.65	2.60
ADDF-PBRH	51.0ab	64.1ab	0.110ab	7.80	2.20

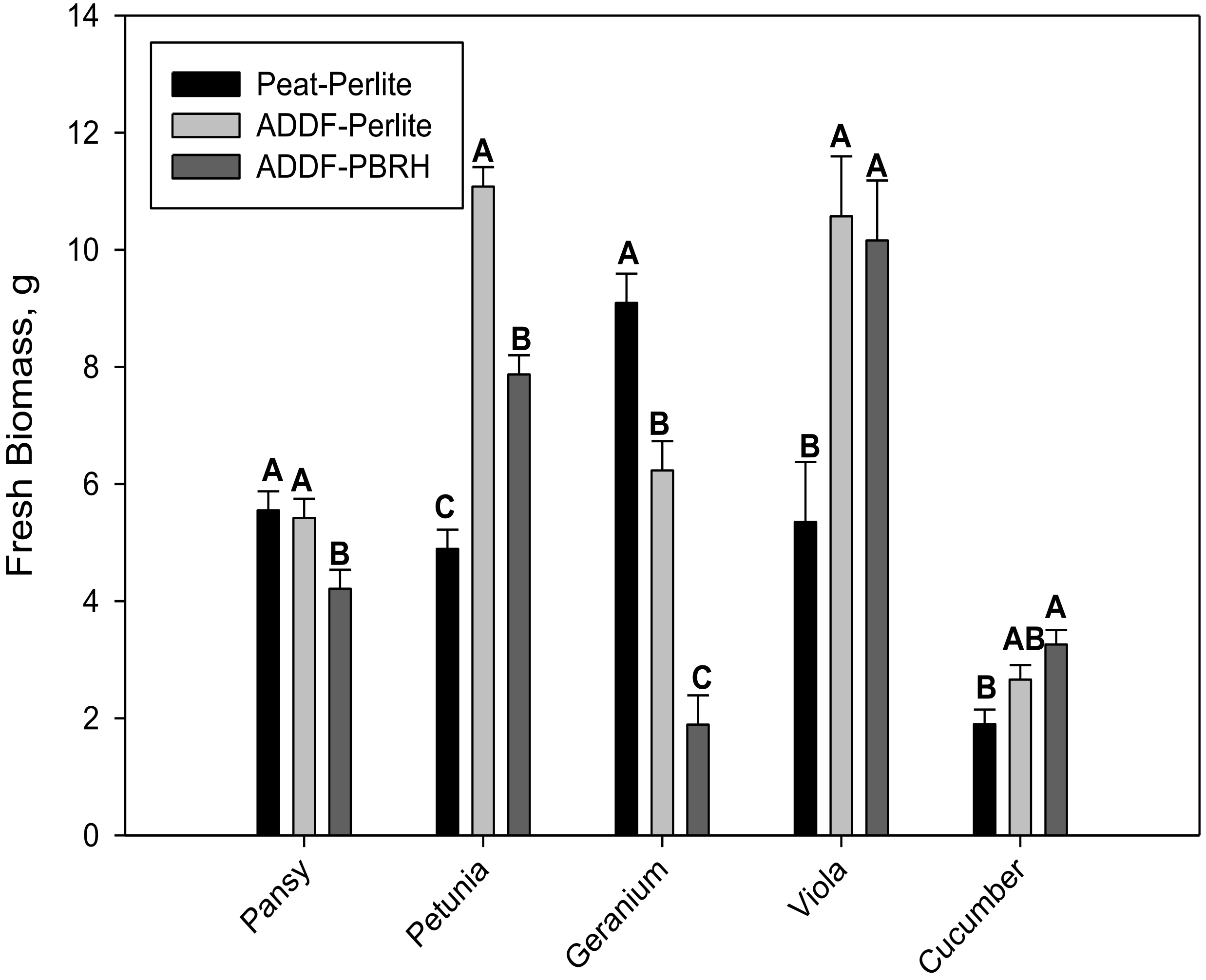
Nursery Media

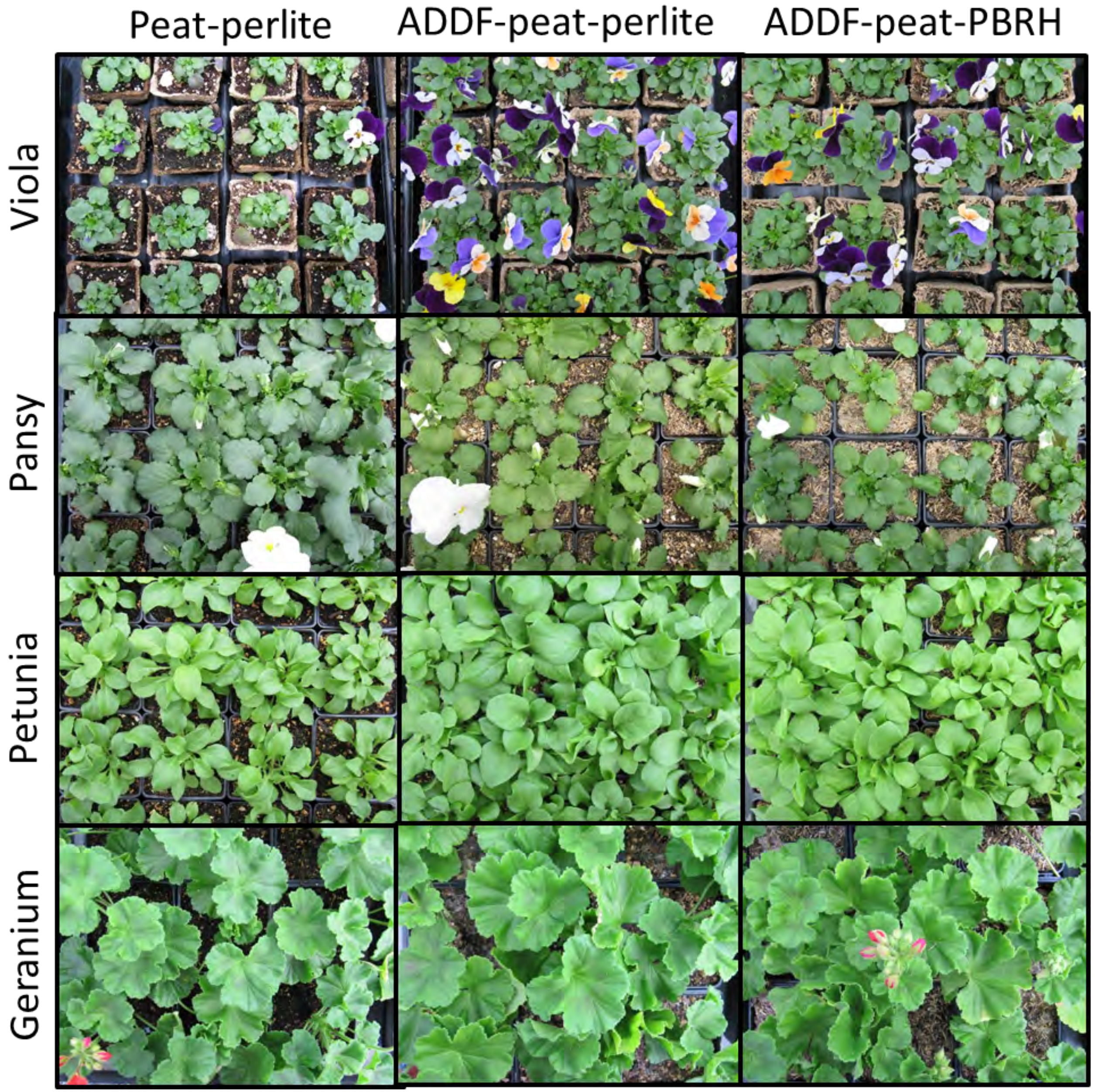
Mix	% of initial volume lost		
	Season 1*	Season 2*	Total
	drip irrigation	overhead irrigation	
Bark-ADDF-sand	0.63	10.25	10.87
Bark-peat-sand	5.37	7.00	12.34

Bedding Plants – Materials and Methods

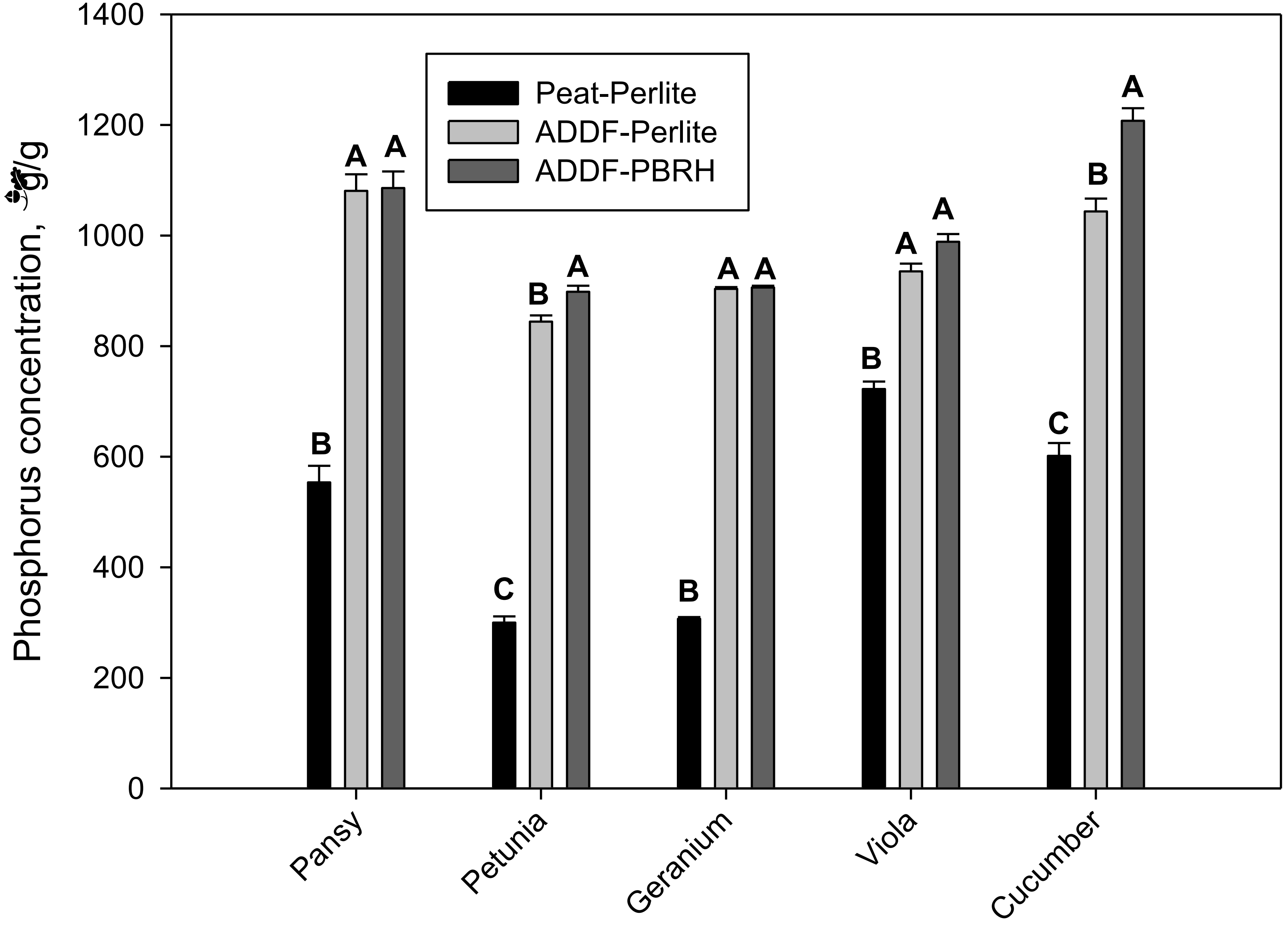
- Peat-ADDF-perlite, peat-ADDF-rice hulls and peatlite
- Crops tested included viola, pansy, geranium, & petunia
- Flood & drain subirrigation with 19-2-19 fertilizer @ 100 ppm N
- Harvested & measured fresh weight
- Analyzed plant tissue to evaluate nutrient availability

Bedding Plants – Plant Growth





Bedding Plants– Tissue Phosphorus



Garden Chrysanthemum – Materials and Methods

- *Chrysanthemum morifolium* 'Hankie Yellow'
- 5 mixes
  - Peat-ADDF-perlite
  - Peat-ADDF-rice hulls
  - Coir-ADDF-perlite
  - Coir-ADDF-rice hulls
  - Commercial peat:perlite (Fafard 1P)
- Grown outdoors

Garden Chrysanthemum – Materials and Methods

- Drip irrigation
- 19-2-19 fertilizer
- Measured fresh weight and canopy volume
- Maturity rating - flowers open
  - 1 = < 30%
  - 2 = 31 – 69%
  - 3 = > 70%

Garden Chrysanthemum Results

Peat-perlite | Peat-ADDF-perlite | Peat-ADDF-rice hulls | Coir-ADDF-perlite | Coir-ADDF-rice hulls

	Volume, dm^3	Fresh weight, g	Maturity rating
Peat-perlite	15.5 a	611 a	2.50 a
Peat-ADDF-perlite	13.3 b	537 b	2.56 a
Peat-ADDF-rice hulls	9.9 d	460 c	1.89 b
Coir-ADDF-perlite	11.6 c	512 b	2.56 a
Coir-ADDF-rice hulls	9.2 d	402 d	2.06 b

Poinsettia – Materials and Methods

- Poinsettia (*Euphorbia pulcherrima* ‘Classic Red’)
- Peat-ADDF-perlite vs peat-perlite
- Flood & drain subirrigation
- 19-2-19 fertilizer @ 100 ppm N

Poinsettia – Materials and Methods

- Measured fresh weight, height and tissue nutrient concentration
- Periodically extracted potting mixes for analysis
  - non-destructive "PourThru" method

Poinsettia - Plant Growth

Peat-Perlite

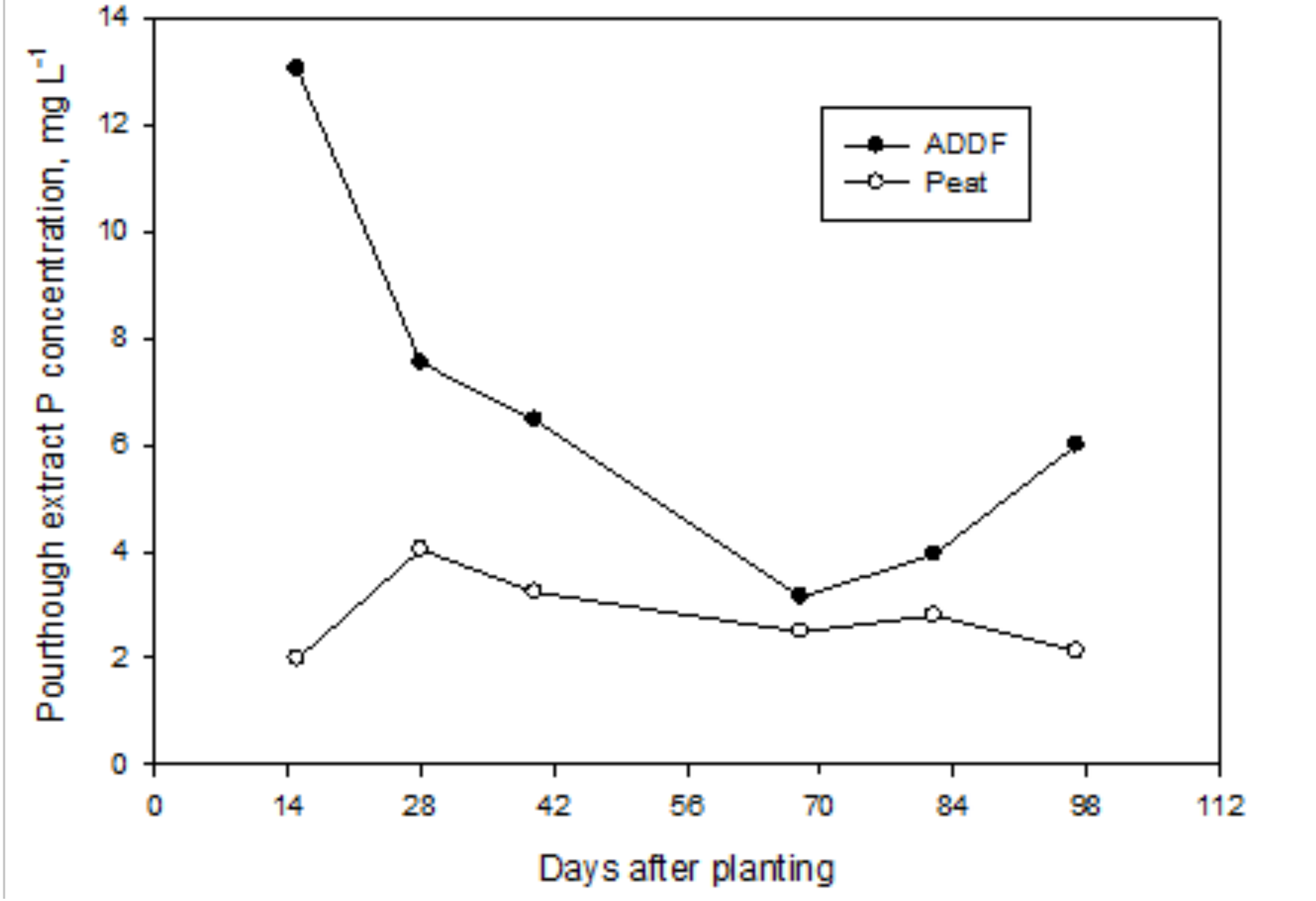
Peat-ADDF-pearlite

Poinsettia – Plant Growth and Tissue Nutrient Analysis

Mix	Fresh weight, g	Dry weight, g	Height, mm
PEAT-perlite	117	15.5	177
Peat-ADDF-perlite	133	18.0	192
Significance	*	*	*

Mix	N	P	K	Ca	Mg	Fe	Mn	Na	Zn
	%	%	%	%	%	mg/kg	mg/kg	%	mg/kg
Peat-perlite	3.5	0.27	2.5	0.6	0.5	218	82	0.2	51
Peat-ADDF-perlite	3.9	0.34	2.3	0.5	0.5	141	108	0.3	86
Significance	*	*	*	*	ns	ns	*	*	*

Poinsettia – Media Phosphorus



Woody Nursery Crops – Materials and Methods

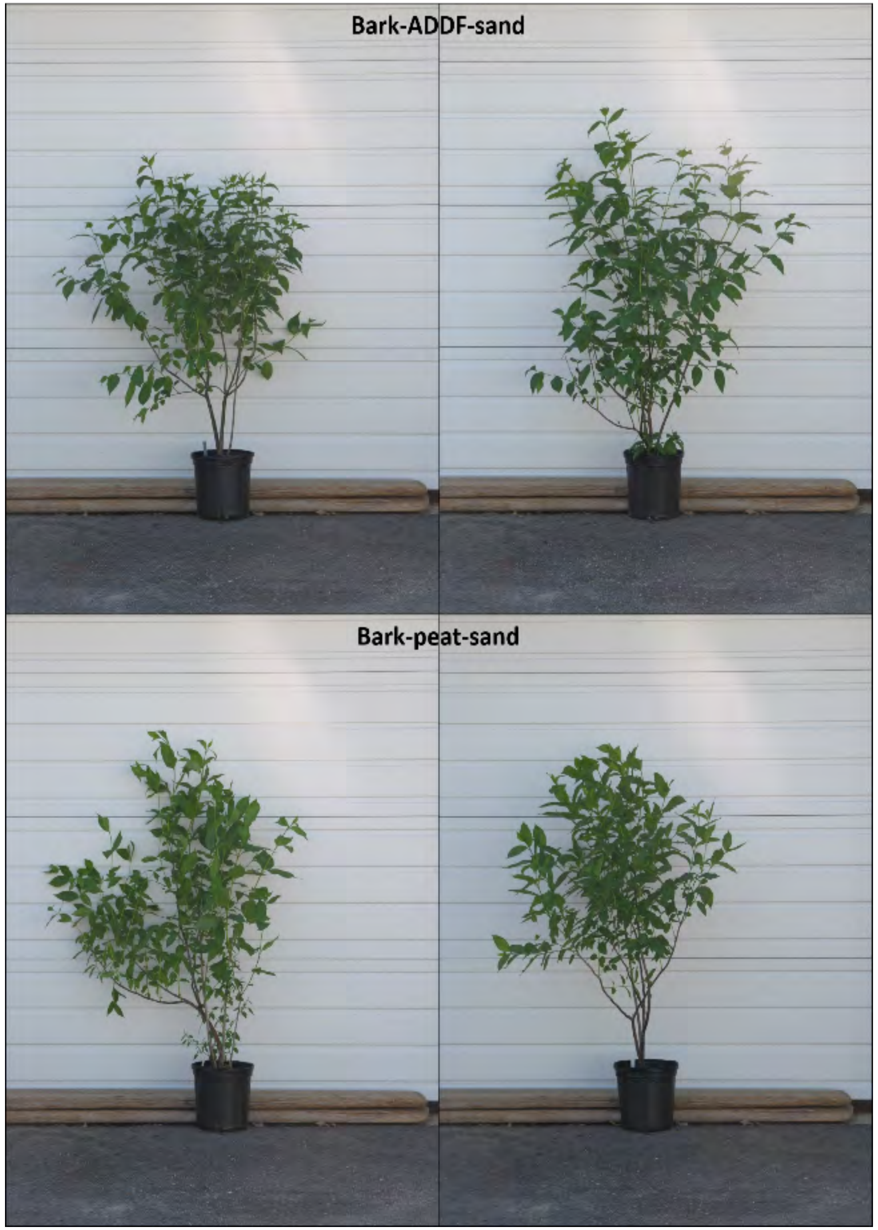
- Nursery mixes
  - 3 bark: 2 peat: 1 sand
  - 3 bark: 2 ADDF: 1 sand
- Crops
  - Button bush *(Cephalanthus occidentalis)*
  - Silky dogwood *(Cornus amomum)*
- Liners planted in #2 nursery pots
- Fertilized with Osmocote 18-6-12 @ 30g/pot

Woody Nursery Crops – Materials and Methods

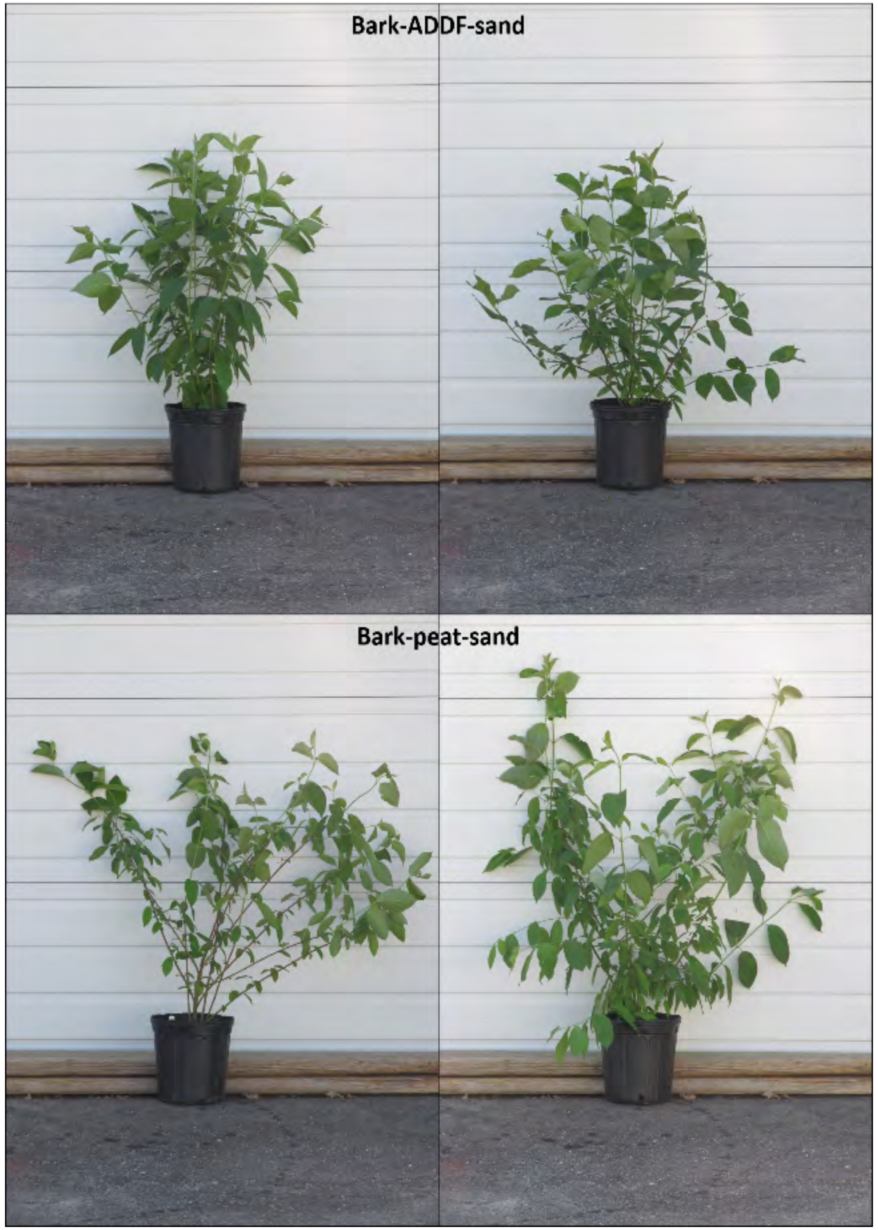
- Grown outdoors under drip irrigation first season.
- Overwintered in unheated hoop house
- Brought into heated double poly covered greenhouse
- Hand watered, no fertilizer
- Harvested following growth flush
- Measured height, caliper, number of new shoots, dry weight

Woody Nursery Crops – Plant Growth

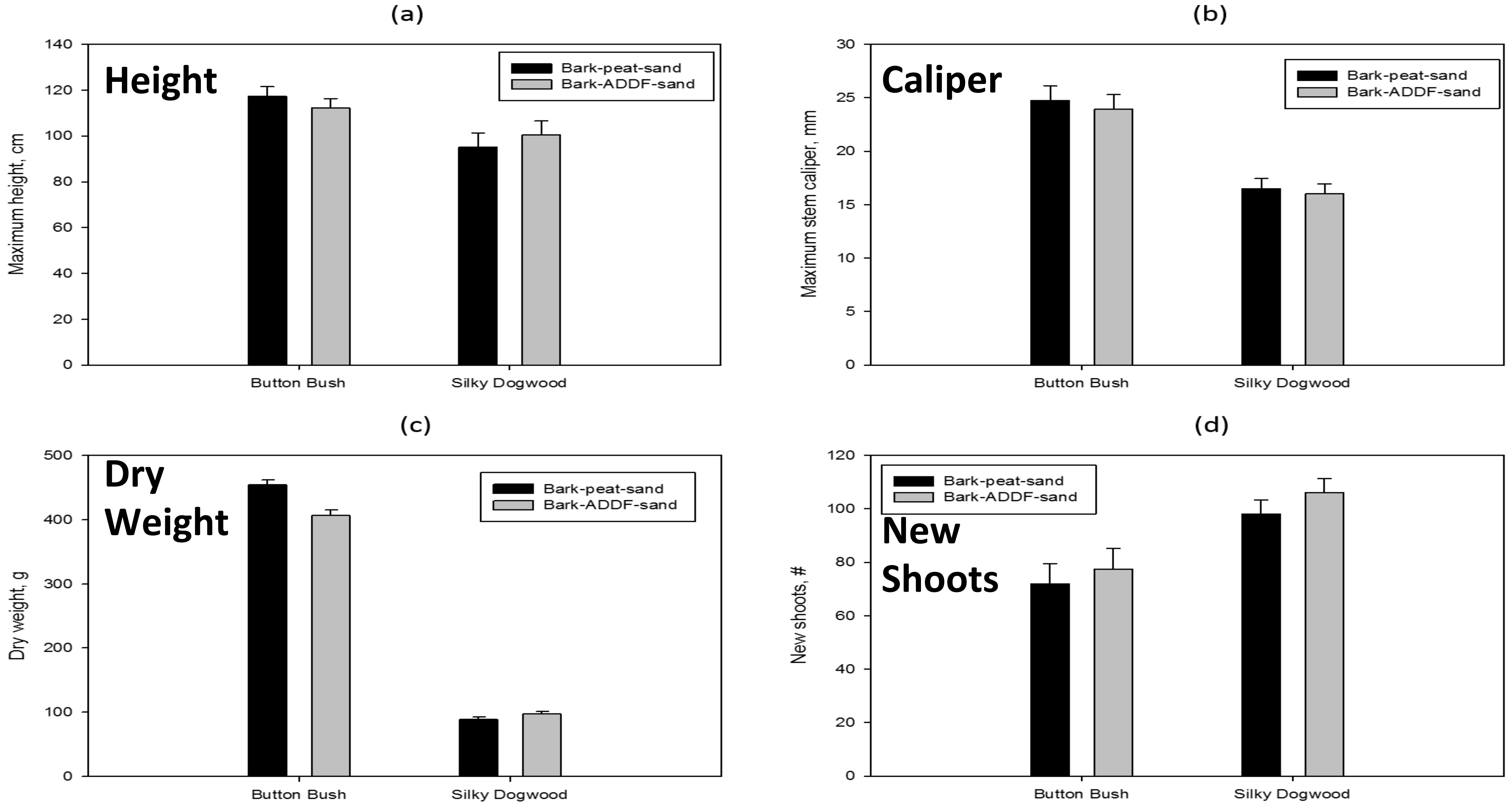
Button Bush



Silky Dogwood



Woody Nursery Crops – Plant Growth



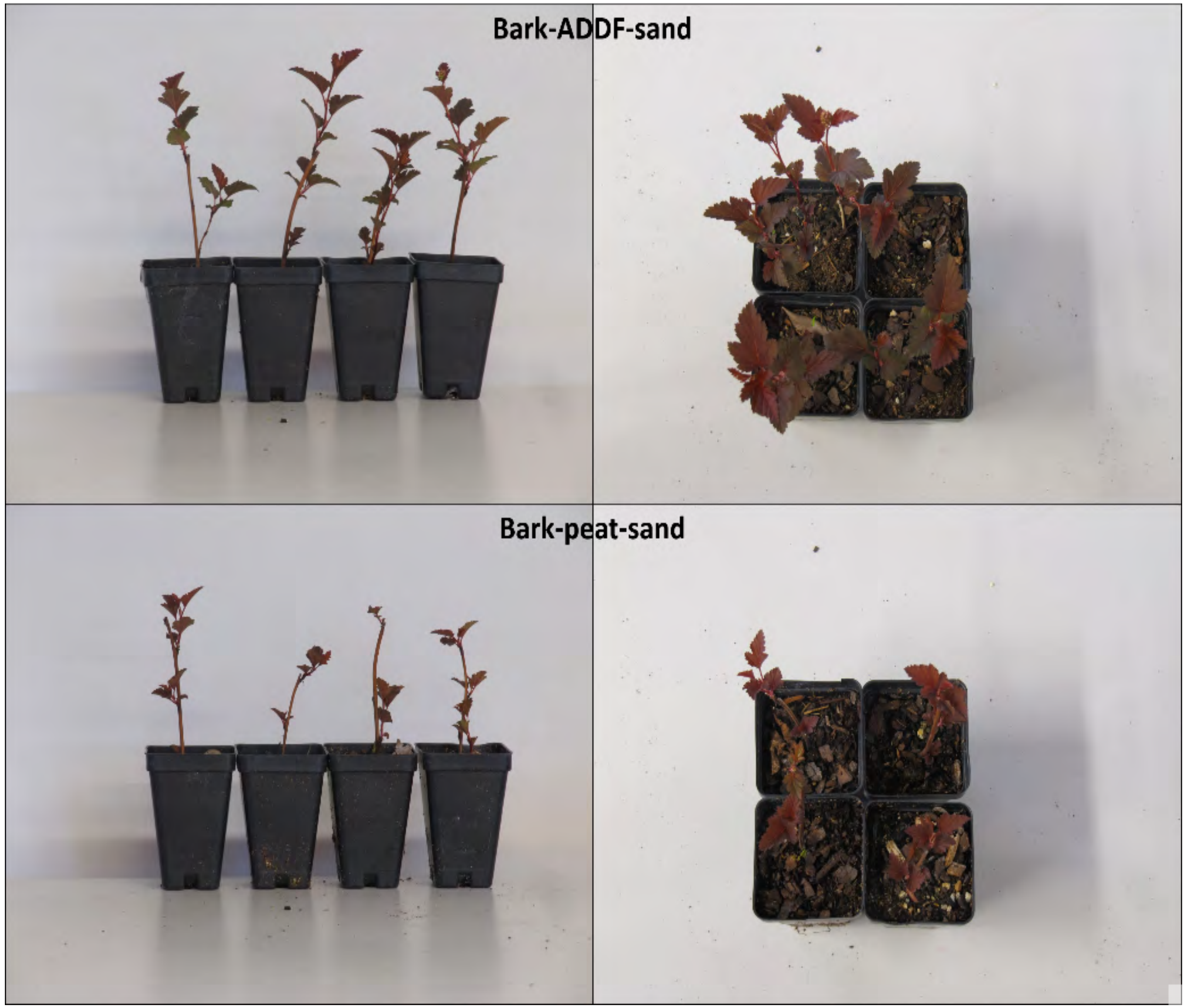
Woody Cuttings– Materials and Methods

- Nursery mixes
  - 3 bark: 2 peat: 1 sand
  - 3 bark: 2 ADDF: 1 sand
- Species
  - Ninebark *(Physocarpus opulifoluis)*
  - Cranberry bush viburnum *(Viburnum opulus*)
- Rooted cuttings planted in 2.5” pots

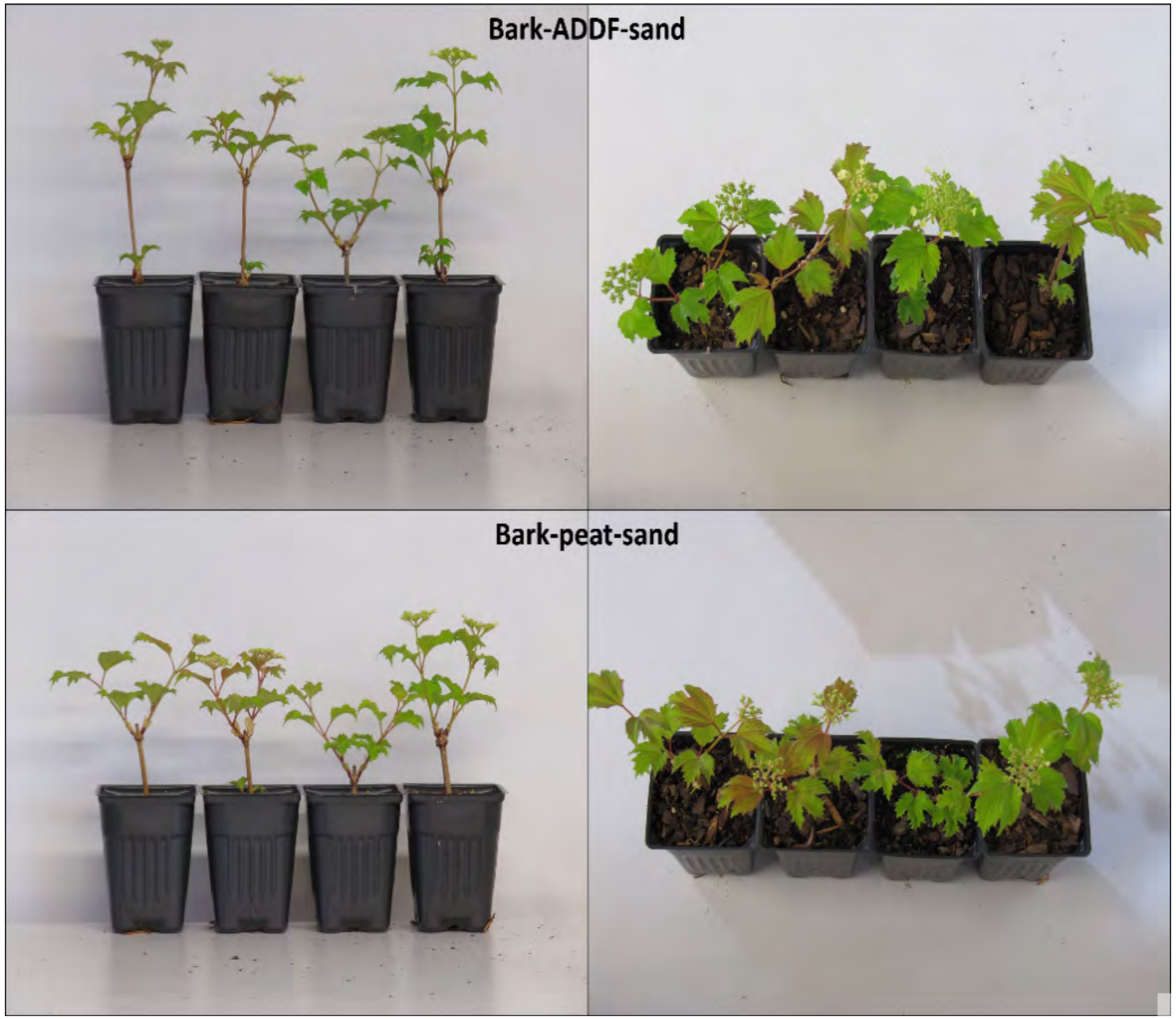
Woody Cuttings– Materials and Methods

- No fertilizer applied
- First season; grown outdoors with hand watering (overhead irrigation)
- Overwintered in cold frame
- Forced out of dormancy in heated greenhouse under overhead irrigation

Woody Cuttings – Plant Growth



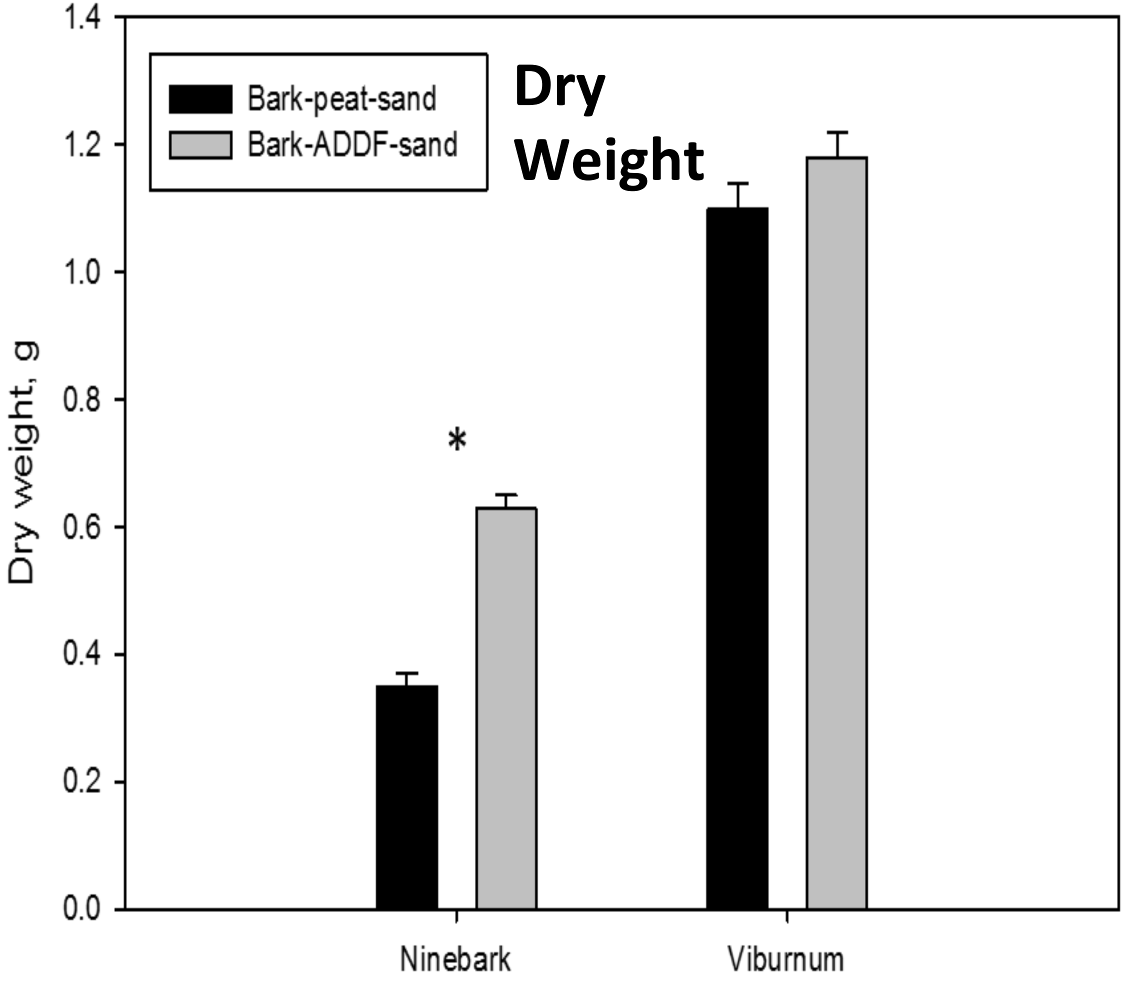
Ninebark



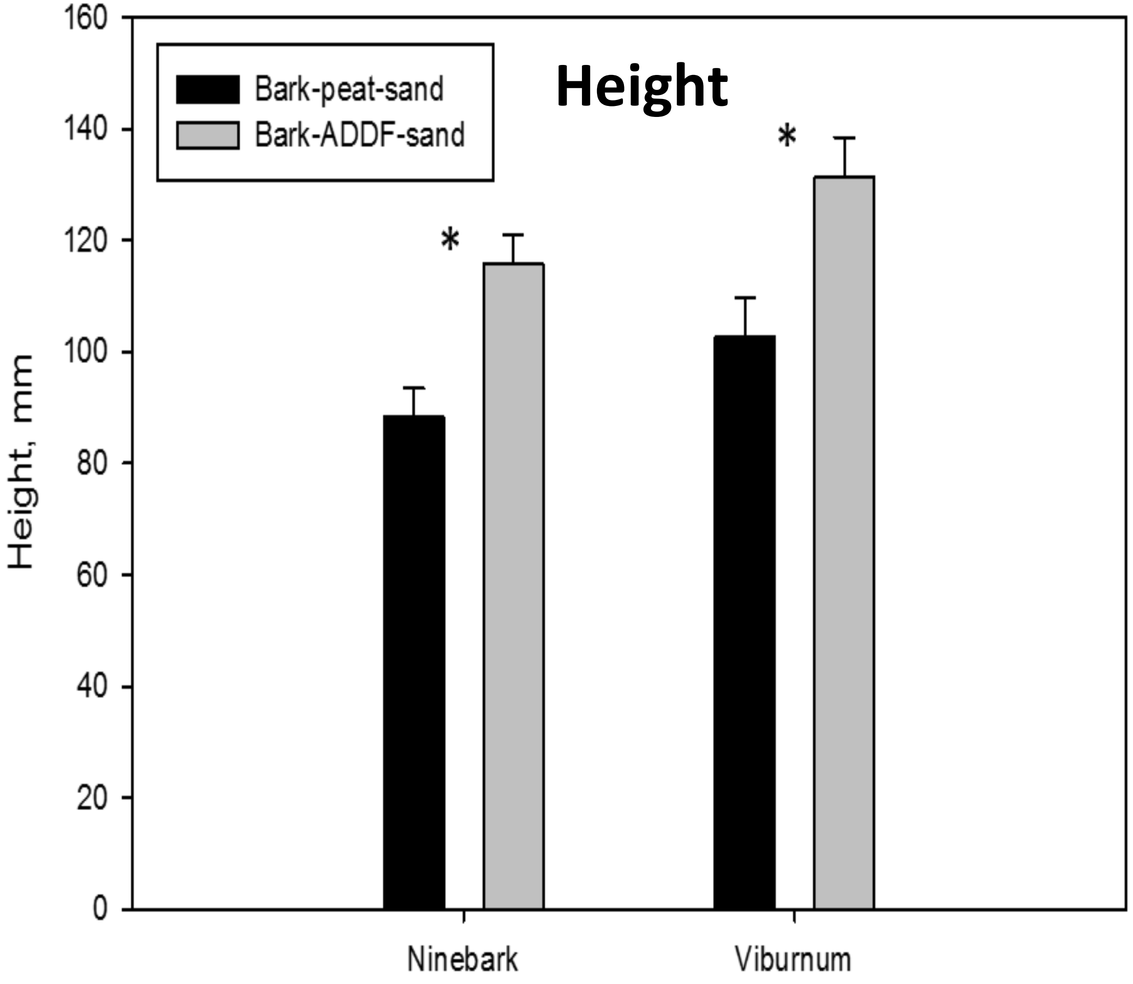
Viburnum

Woody Cuttings – Plant Growth

(a)



(b)



Herbaceous perennials

- Bark-peat-perlite vs. bark-ADDF-perlite
- Species
  - Brunnera (*Brunnera macrophylla* ‘Jack Frost’)
  - Shasta daisy (*Lucanthemum superbum* ‘Whoops-a-Daisy’)
  - Phlox (*Phlox paniculata* ‘David’)
  - Liatris (*Liatris spicata* ‘Kobold Original)
  - Coreopsis (*Coreopsis verticillata* ‘Moonbeam’)

Herbaceous Nursery Crops

- Fertilized with 6g/pot Osmocote 18-6-12
- Plant growth evaluated based on individual species growth habits
- Overhead irrigated and leachate collected for analysis.
- Measured nutrient leaching from unplanted pots with mixes, raw ADDF and peat

Herbaceous Nursery Crops – Plant Growth

Brunnera

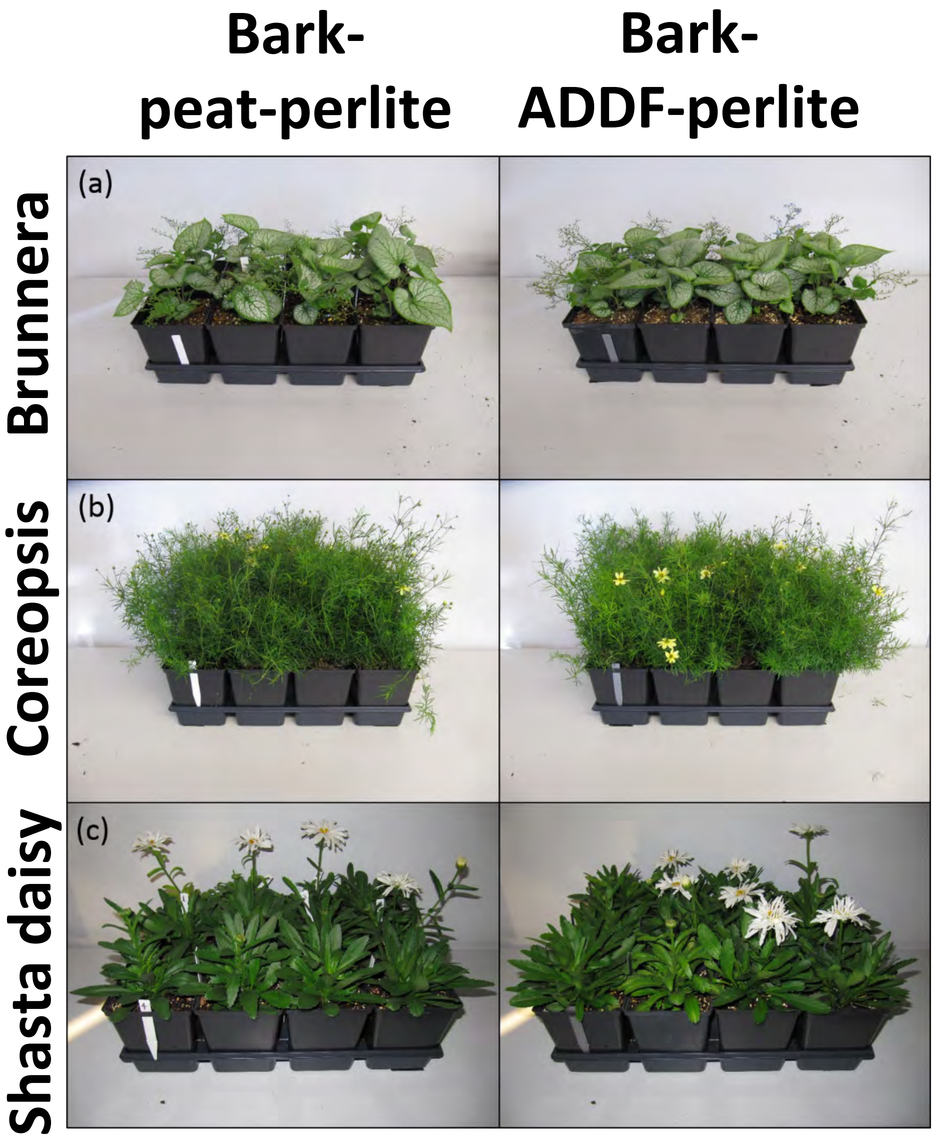
Mix	Flower spikes	Maximum flower spike length, mm	Volume, cm^3
Bark-ADDF-perl	2.4	172	1017
Bark-peat-perl	1.8	171	791

Coreopsis

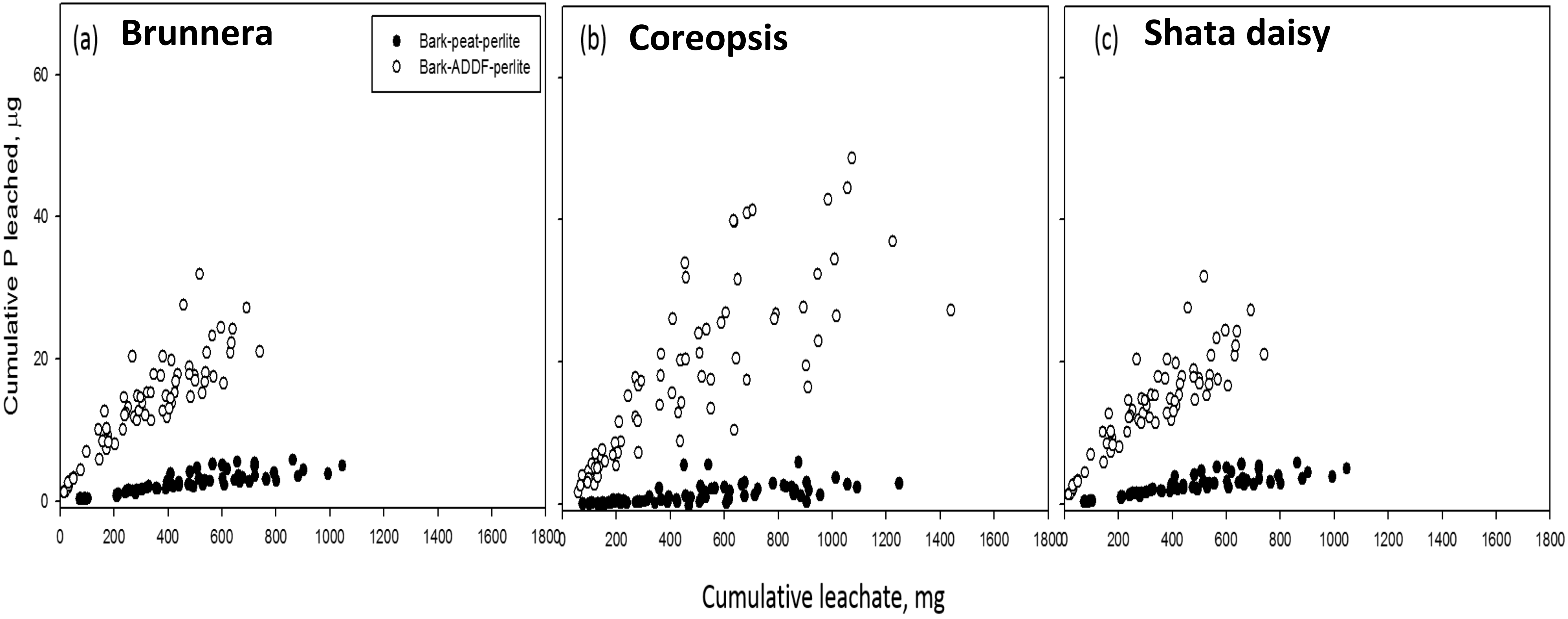
Mix	Dry weight, g
Bark-ADDF-perl	8.81
Bark-peat-perl	9.24

Shasta daisy

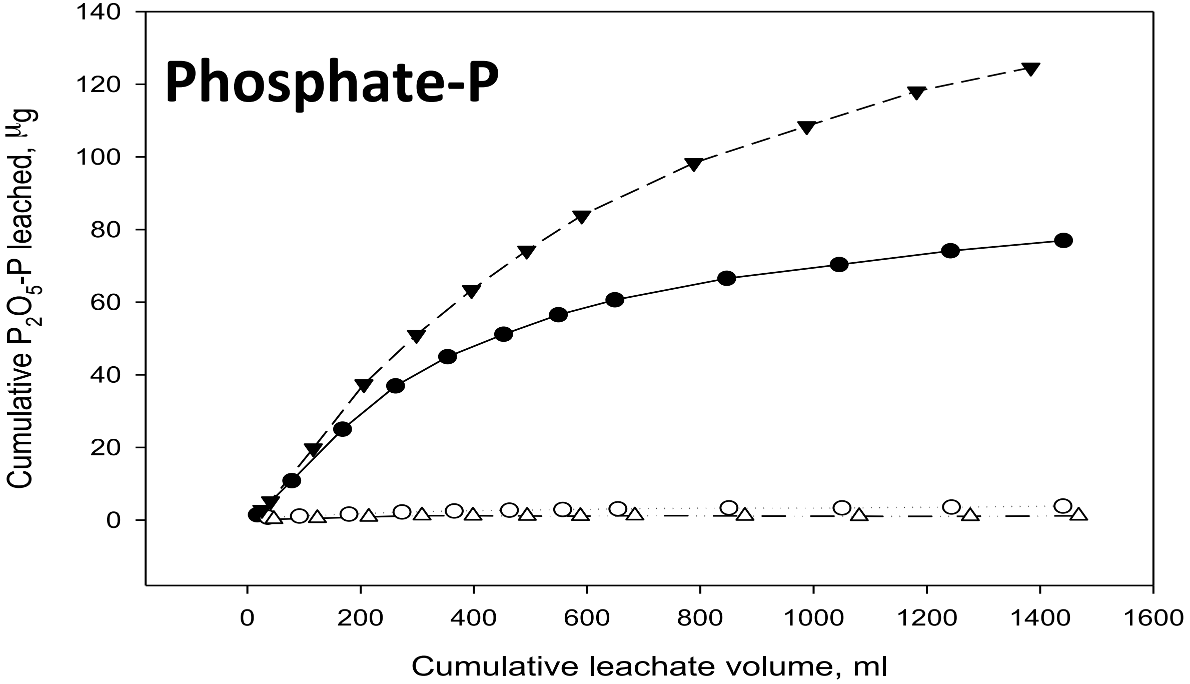
Mix	Dry weight, g*	Flowers
Bark-ADDF-perl	**4.29**	1.75
Bark-peat-perl	**2.74**	1.33

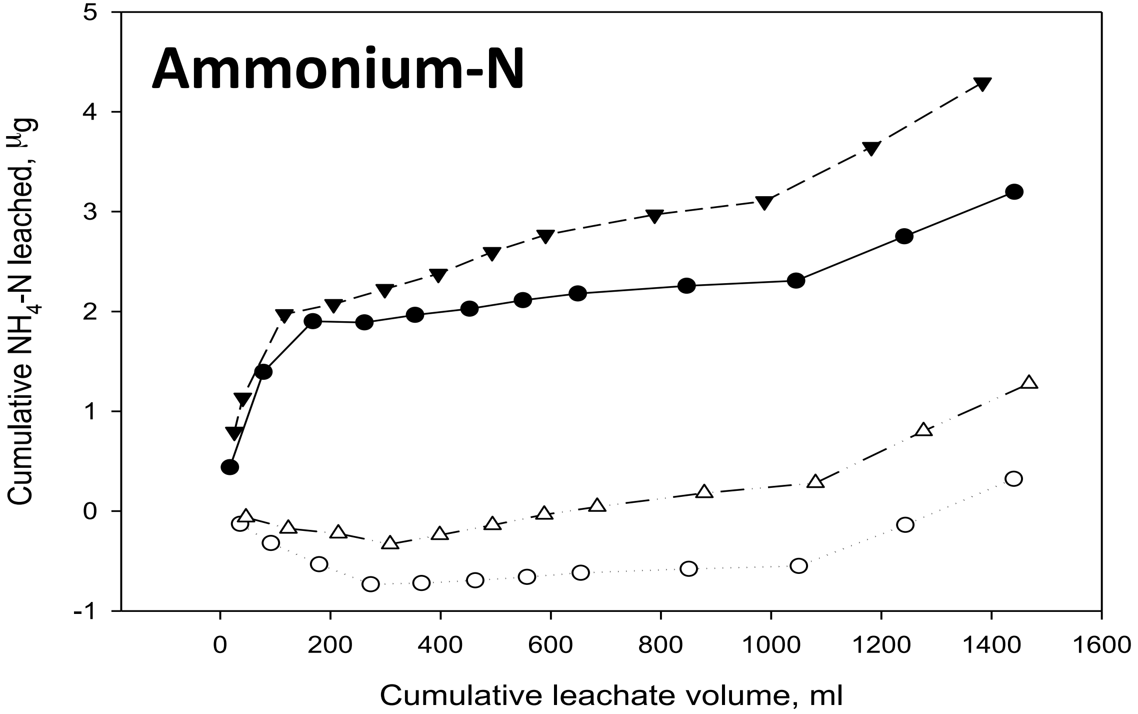


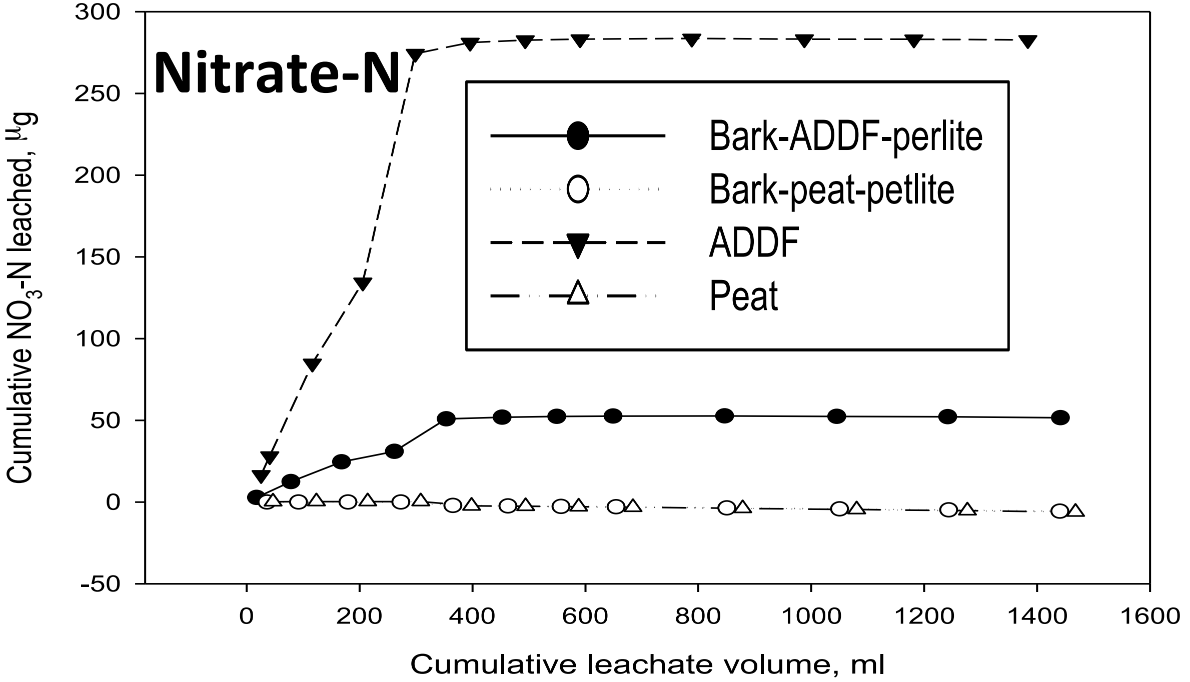
Herbaceous Nursery Crops – Phosphorus Leaching



Nitrogen & phosphorus leaching from unplanted pots







Conclusions

- ADDF-containing SPM have physical properties similar to standard commercial SPM
  - ADDF may not be as stable as peat
- ADDF is a significant source of plant available N & P
  - Potential for N & P leaching from ADDF
- ADDF can be an effective substitute for peat in SPM

Conclusions

- Limitations to using ADDF
  - pH control
  - soluble salts
  - long-term physical stability
  - irrigation management

Acres USA

Anaerobically Digested Dairy Fiber - a Renewable Replacement for Peat

By John R. Lamont and George C. Elliott

Researchers at the University of Connecticut recently finished a project aimed at finding a new use for dairy waste as a valuable horticultural product. Anaerobically digested dairy fiber (ADDF), a by-product of methane extraction from dairy manure, was evaluated as a renewable alternative for peat in a wide variety potting mixes for both greenhouse and nursery crops. A diverse selection of 18 greenhouse and nursery crops were grown in 9 potting mixes with and without ADDF and evaluated for growth, quality and nutrient uptake. Mixes with ADDF as a partial or complete replacement for peat produced plants of equal or better size and quality to those grown in a standard peat-based mix for most crops. All plants grown in ADDF-containing media had greater tissue phosphorus concentrations than those grown in peat-based mixes.

Growing concerns over the environmental impact of dairy manure management has led to a push for dairy farmers to adopt anaerobic digestion to process manure. If manure is not stored and processed properly it can release significant amounts of nitrogen, phosphorus and methane, a greenhouse gas almost 25 times as powerful as carbon dioxide, into the environment. Anaerobic digester systems can be used to reduce odor, stabilize and contain manure as well as capture methane for use as a biogas fuel. Methane can be sold or used for onsite energy production. Currently, the fibrous solids left over after digestion is complete (ADDF) are usually used for animal bedding or spread on crop field as is done with raw manure. ADDF has a more fibrous structure than raw or composted manure. Finding a more lucrative use for ADDF would generate new revenue for dairy farmers and incentivize the adoption of anaerobic digester systems.

Environmental concerns may also be leading to changes in the horticultural industry. Peat has played an important role in the horticultural industry for decades, serving as a primary component of most potting mixes since the introduction of Cornell University's "peat-lite" mix in the 1960s. Peat has a distribution of large and small pores that gives it excellent water holding capacity and aeration, ideal for the growth of plant roots. Peat is also easily adaptable to a wide variety of growing practices, media blends and crops. Peat owes much of its desirable attributes to the way it is formed; under anaerobic conditions in peat bogs. These conditions preserve the fibrous cellulose structure of the plants the peat is formed from. Peat is harvested by cutting strips from peat bog up to 1 meter deep. Peat only reforms at a rate of 1-2mm per year so each harvest represents hundreds of years of peat formation. While efforts to "restore" peat bogs after harvest are commendable, it is questionable whether ecological functionality can ever be completely restored or whether peat is a truly renewable resource. These concerns have led to a search for more sustainable alternatives to peat in potting media. One potential alternative is ADDF.

Marketing ADDF as a useful horticultural material rather than simply manure could, in conjunction with methane production, become yet another source of income for dairy farmers and provide a partial solution to the waste management problems associated with raw manure.

Methane extraction from manure shows great promise as a supplementary revenue source for dairy farmers but revenue generated by energy production alone is often not enough to offset the capital costs of constructing anaerobic digesters. If ADDF were proven as a high quality media component, it would be a value-added product to augment dairy profits. The demand for ADDF from growers would be an added incentive for dairy farmers to adopt the more sustainable anaerobic manure digestion systems. Additionally, if ADDF were used in a growing media, nutrients that would otherwise be lost as pollutants would be used for plant nutrition.

Greenhouse mixes are often based on the classic Cornell "peat-lite" mix and contain a large proportion of peat; up to 80% or more of the total mix volume. Replacing all or part of it could represent a great potential to significantly reduce demand for peat. While nursery mixes usually contain a smaller proportion of peat than greenhouse mixes, nursery crops are generally grown in larger pots and require a larger volume of media so a smaller proportion of peat in a larger volume of media still accounts for a significant amount of peat consumed.

A preliminary analysis of various ADDF-containing media helped to identify some blends that were most similar to a standard peat-based mix for use in subsequent plant growth trials. Mixes that combined ADDF with other alternative media components such as coconut fiber (coir) and parboiled rice hulls (PBRH) were also evaluated to determine the adaptability of ADDF in a diversity of mixes. The media analysis showed that the physical properties, including porosity, water holding capacity and bulk density of mixes with peat-ADDF-perlite, peat-ADDF-PBRH, coir-ADDF-perlite and coir-ADDF-PBRH in a 2:2:1 ratio were similar to a peat-perlite greenhouse mix in a ratio of 4:1. Likewise, nursery mixes containing bark-ADDF-sand or bark-ADDF-perlite in a 4:2:1 ratio had similar physical properties to analogous mixes with peat in place of ADDF.

Mixes containing ADDF did, however, differ from peat-based mixes in some chemical properties. Raw ADDF has a high pH (7.5 or higher) whereas peat is generally acidic (below pH 5). The high pH of ADDF makes it unusable as a complete replacement for peat in greenhouse mixes unless it is amended with elemental sulfur. However, adjusting the pH with sulfur can be tricky. Fortunately, in the preliminary media analysis, we found that when ADDF and peat are blended in 1:1 proportion they neutralize each other and arrive at a pH suitable for plant growth (around 6.0-6.5). However, when ADDF was mixed with near pH neutral coir, the final product had a pH slightly higher than ideal for plant growth (6.7-7.0). In a standard peat-perlite mix, lime is added both to raise the pH of the mix and to supply plants with calcium. In the ADDF-containing mixes, pH was in an acceptable range before liming so gypsum was used to add calcium without greatly changing the pH. All ADDF-containing mixes also had high levels of soluble salts. Phosphorus concentrations in ADDF-containing mixes were also much greater than in the peat-based control mixes.

Plant Growth Trials

Bedding plant species including pansy, viola, petunia and geranium were grown in a greenhouse in either the peat-perlite, peat-ADDF-perlite or coir-ADDF-perlite media. Upon harvest, plants were weighed and tissues were analyzed for nutrient concentration. Plant quality was evaluated subjectively. Growth responses varied between mixes and species with some species, such as viola and petunia, responding more favorably to ADDF-containing mixes and others, such as pansy, responding less favorably to the ADDF mixes. Regardless of growth response, all plants grown in ADDF-containing mixes had greater tissue phosphorus concentrations.

Cyclamen and garden mums were grown in five different mixes: the peat-ADDF-perlite, peat-ADDF-PBRH, coir-ADDF-perlite and coir-ADDF-PBRH and a control of the peat-perlite mix. Cyclamen and garden mums grown in the peat-ADDF-perlite grew to be of a marketable size and quality. Chrysanthemum was evaluated by measuring canopy volume, weight, maturity rating and tissue nutrient concentration. Cyclamen was evaluated by measuring canopy volume. The quality of both crops was also evaluated subjectively. The mixes that incorporated other alternative media components, such as coir and PBRH, generally produced less favorable results. Overall, the more a mix deviated from the standard peat-perlite mix, the less favorable results it produced. For example, the coir-ADDF-PBRH mix, which contained none of the same components as the standard peat-perlite mix produced the smallest, lowest quality cyclamen and mums. As in the bedding plant trial, all plants grown in ADDF-containing mixes had greater tissue phosphorus concentrations.

The results of these floriculture and greenhouse crop trials showed that the most consistently favorable results could be obtained with the peat-ADDF-perlite mix. With this in mind, a trial with the lab rat of floriculture crops, poinsettia, was conducted with the peat-ADDF-perlite and the peat-perlite mixes. Height and weight measures and subjective observations were used to evaluate plant growth and quality. Poinsettias grown in the peat-ADDF-perlite mix were larger and denser than the plants grown in the peat-perlite mix. They also had greater tissue phosphorus concentrations. The elevated phosphorus concentrations in the tissues of bedding plants, chrysanthemum, cyclamen and poinsettia show that ADDF contains significant quantities of plant available phosphorus. This phosphorus may also be easily leached so it was more carefully monitored in the following herbaceous nursery crop trial.

Because nursery crops are usually more robust than greenhouse crops, they have great potential to be grown in media containing alternative components. Five herbaceous nursery crops including coreopsis, phlox, brunnera, leucanthemum and liatris were grown in either the bark-peat-perlite or bark-ADDF-perlite mixes in a greenhouse. Upon harvest, plants growth and quality were evaluated based on various crop-specific parameters. Plant available phosphorus may be easily leached from pots and become a pollutant so in this trial all leachate was collected and analyzed for phosphorus concentration to estimate potential leaching from ADDF mixes. There were no measured differences between plants grown in the bark-ADDF-perlite mix and the bark-peat-perlite mix except in coreopsis, which had slightly larger plants in the ADDF-containing mix. In the leachate that was collected during this trial, elevated concentrations of phosphate were measured from the ADDF-containing mix throughout the trial.

Woody nursery crops including liners of button bush and silky dogwood and rooted cuttings of ninebark and cranberrybush viburnum were grown in either the bark-peat-sand or bark-ADDF-sand nursery mixes. Crops were grown outdoors for one season, overwintered and evaluated after leafing out in the second season. There were no differences between button bush and silky dogwood grown in the two mixes. The ninebark and cranberrybush viburnum grown in the bark-

ADD-sandF mix leafed out faster and grew to be larger than the cuttings grown in the bark-peat-sand mix. Button bush and silky dogwood grown in the bark-ADDF-sand mix grew to a similar size and quality of those grown in the bark-peat-sand mix.

CONCLUSIONS

For most crops, at least one mix containing ADDF yielded plant growth results equal to or better than the plants grown in the standard peat based mix. In some crops, such as viola, petunia, poinsettia, ninebark and cranberrybush viburnum, plants grown in an ADDF-containing mix were of much higher quality than those grown in the peat-based mix. This shows that it is possible to use ADDF as a media component to produce high quality ornamental plants. The variability in results was likely due to the fact that all management decisions were based on established management practices for peat-based mixes. Slight differences between ADDF and peat likely necessitate slightly different growing practices to achieve optimal results from ADDF. More research will be required to develop the best management practices for ADDF containing mixes.

The differences in nutrient content between ADDF and peat certainly calls for a different approach to fertilizing ADDF mixes. ADDF contains significant quantities of soluble phosphorus that can provide plants with supplemental nutrition and also contribute to pollution if it is leached. Low phosphorus fertilizers and irrigation systems that minimize leaching should be used with ADDF mixes. Any grower who is considering using any new mix or alternative media component should run small trials to make sure the new media is compatible with their systems and crops.

Using ADDF as a substitute for peat in potting mixes offers solutions multiple environmental issues as well as economic benefits to dairy farmers, growers of containerized crops and diversified farm operations.

Integrating Dairy Waste and Potted Plant Production: A Case Study in Alternative Potting Mixes

By John R. Lamont & George C. Elliott

When we think of the ecology of agricultural systems we often think of the ecology of a field or a single farm but there is a broader agroecosystem that connects various sectors of agriculture with consumers, the environment and one another. In a recently completed project at The University of Connecticut (UConn) researchers worked to strengthen a symbiotic relationship between the dairy industry and horticultural industry while reducing the impact of both of these industries on the environment. This work was focused on testing the potential of anaerobically digested dairy fiber (ADDF), a by-product of methane extraction from dairy manure, as a renewable alternative to peat in potting mixes. A wide variety of greenhouse and nursery crops were grown successfully in potting mixes with ADDF as a partial or complete replacement for peat. These trials can serve as a case study in recycling an agricultural by-product into a valuable renewable horticultural material.

Peat based potting mixes have been an industry standard for decades but concerns over the environmental impacts of its harvest have led many to question its sustainability. Peat is mined from peat bogs which serve a variety of ecological functions including carbon sequestration and regulating water movement and quality. Harvesting peat from deep in the bogs can quickly remove hundreds of years of peat accumulation and release significant amounts of carbon into the atmosphere. This drastically alters the chemical, physical and biological composition of peatlands and may even compromise the ecological functionality of "restored" peat bogs. Most peat is produced in cold, northern regions and must be shipped long distances to more temperate horticultural areas contributing further to carbon emissions. All of these environmental concerns have fostered a search for more sustainable alternatives to peat. One of the potential alternatives is ADDF.

Dairy manure usually ends up getting spread on crop fields. While amending crop fields with manure improves soil structure and recycles some nutrients from the manure into the crop, much of the nutrition can be lost in the form of runoff. Also, when manure is applied to the same fields year after year nutrients, especially phosphorus, can accumulate excessively and slowly leach out, polluting the environment for decades. Additionally, manure releases methane as it decomposes. Methane is a greenhouse gas 25 times more powerful than carbon dioxide and poor manure management contributes significantly to total methane emissions. Anaerobic digestion is an alternative way to process manure in which manure is fermented in an oxygen-free environment. Anaerobic digestion allows farmers to reduce odors and collect the methane produced by the fermentation process for use as a biofuel. After anaerobic digestion is complete, the solid and liquid fractions are separated; the solid fraction is ADDF.

Peat and ADDF have many similarities in how they are formed and in their physical properties. Both materials are formed under anaerobic conditions in which they are fermented by similar microbes. Anaerobic digesters have even been referred to as "short term, renewable peat bogs". An analysis of physical properties showed that peat and ADDF have similar water holding capacity, porosity and bulk density. There are, however, some important differences between the chemistry of peat and ADDF. Peat is quite acidic with a pH less than 5, whereas ADDF is somewhat alkaline, with a pH greater than 7.5. ADDF also contains significant quantities of soluble nutrients, especially phosphorus. However, it also contains higher concentrations of total soluble salts than peat. In the growth trials at UConn, the availability of these nutrients to plants was evaluated to determine if additional nutrition provided by ADDF could reduce fertilizer inputs.

Based on preliminary media analyses, a variety of mixes with properties similar to standard peat-perlite or bark-peat-sand mix for greenhouse and nursery mixes, respectively, were blended for plant growth trials. In the greenhouse mixes, 50% of the peat was replaced with ADDF so the acidity of the peat and alkalinity of the ADDF could neutralize one another and a pH suitable for plant growth could be attained. In a standard peat-perlite mix, lime is often used to neutralize the natural acidity of peat and supply calcium to the plants. In the peat-ADDF-perlite mixes, the acidic peat was already neutralized by the ADDF so gypsum was added to supply calcium without altering the pH. The versatility of ADDF in a variety of mixes was tested by making mixes that contained coir (coconut fiber) as a replacement for peat or parboiled rice hull (PBRH) as a replacement for perlite in addition to ADDF.

Bedding plants, vegetable seedlings, garden mums, cyclamen and poinsettia were grown in a variety of greenhouse mixes containing ADDF. A mix with a 2:2:1 ratio of peat:ADDF:perlite produced plants of an acceptable size and quality for most greenhouse crops tested. Results varied somewhat between crops and potting mixes. In some cases, as with petunia, plants grown in the ADDF-containing mix were even larger and lusher than those grown in the standard peat-perlite mix whereas other crops, such as pansy, grew better in the standard peat mix. Some of the mixes that contained coir or parboiled rice hulls in addition to ADDF produced less favorable growth results. Generally, the more a mix differed from the standard peat-perlite mix, the less favorable the growth results were. Almost all plants grown in the ADDF mixes had greater tissue phosphorus concentrations than those grown in the standard peat-perlite mix.

The trial with vegetable seedling produced some of the most promising results of all the greenhouse trails. Squash and cucumber seeds were planted in 3" pots with one of three mixes. The control mix was composed of peat and perlite in a 4:1 ratio amended with lime. The other two mixes were peat-ADDF-perlite and peat-ADDF-PBRH each in a 2:2:1 ratio each with four grams of gypsum per liter of mix. Plants were watered overhead until they had established root robust systems. Plants were grown in a greenhouse under a light fertilizer regime to better observe nutrient availability from ADDF. Plants growth and phosphorus uptake were evaluated based in fresh weight and shoot tissue phosphorus concentration upon harvest. Squash grew to the same size in all mixes and cucumber seedlings grown in the peat-ADDF-PBRH mix were larger than seedlings grown in the standard peat-perlite mix. Seedlings grown in the ADDF mixes also has great tissue phosphorus concentrations than those grown in the peat-based mix.

In the nursery mixes peat made up a much smaller proportion of the mix than in greenhouse mixes (slightly less than 30% vs. 80%) so ADDF was an acceptable replacement for all the peat in the mix rather than only replacing 50% of the peat. All nursery crops grown in ADDF-containing mixes grew to a similar or better size and quality than those grown in the peat-based nursery mixes. The consistently favorable results of the nursery crop trials may have been due to the smaller proportion of peat being replaced in the nursery mixes or that nursery crops are generally more robust than greenhouse and floriculture crops and may have been better able to tolerate suboptimal root zone conditions. Despite the smaller proportion of peat in nursery mixes, nursery crops are grown in containers with much larger volumes, which require greater volumes of media than greenhouse crops so using ADDF as a replacement for peat in nursery mixes could still significantly reduce demand for peat. Further research could establish if some of the bark component could be replaced with ADDF.

In these trials, management decisions were based on established cultural recommendations for peat-based control mixes. In many cases, irrigation management that was optimal for the standard peat-perlite mix was less than optimal for other mixes; this was likely the case for the unfavorable results observed in some of the greenhouse mixes. A wider variety of mixes and mix components may be able to produce good results if growing practices are adjusted to account for differences in mixes. ADDF was shown to be a significant source of plant available phosphorus so fertilization regimes would need to be adjusted accordingly to keep from over fertilizing. The best growing practices for a new mix can be developed through trial and error.

These trials have shown that ADDF can be used as a replacement for peat in potting mixes for a wide variety of greenhouse and nursery crops and reduce the need for phosphorus fertilizers. A highly integrated ecosystem is generally highly resilient as well. To move forward in a sustainable way, it is important to find ways to integrate agricultural sectors and find ways to find new, valuable uses for wastes and by-products. Using ADDF in potting mixes would create a new link in the broader agroecosystem and make it stronger as a whole. This research also serves as a valuable case study for anyone trying to develop potting mixes from alternative components.

CURRICULUM VITA

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Ph.D. 1981 North Carolina State University; Horticultural Science and Soil Science
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Professional Experience:

1989-2015 Associate Professor of Horticulture, University of Connecticut
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1981-1983 Postgraduate Researcher, University of California, Davis
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Field of Specialization/Research Interests:

I am interested in soil-plant relations with application to floriculture and ornamental horticulture.

My research is focused on the biological, chemical and physical properties of container media used for production of greenhouse and nursery crops. Specific research topics include:

- nutrient availability from controlled-release fertilizers, organic fertilizers and composts
- nutritional and lime requirements for container-grown crops
- water retention, lime reactions, pH buffering, and pH adjustment in soilless potting mixes
- biological controls for soilborne diseases affecting container-grown crops
- evaluating novel materials such as granulated rockwool and anaerobically digested dairy fiber as potting mix components
- hydroponic systems and nutritional management

Recent and Representative Publications:

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Digested Dairy Manure To High-End Potting Soil

Text

An anaerobic digester development company launched a bagged potting soil product to utilize digested dairy manure fibers and improve long-term success of facilities.

Nora Goldstein
BioCycle July 2014, Vol. 55, No. 6, p. 48

Magic Dirt is blended with natural recycled materials and packaged in one cubic foot bags that are currently sold in Idaho and parts of several other Western states.

Robert Joblin and Ted Sniegocki of Cenergy USA based in Little Rock, Arkansas, are not horticulturalists or agronomists. But they are anaerobic digester developers and when falling rates for renewable energy and the loss of the federal Investment Tax Credit grant hit at the same time, the financial models they had been using "fell down." The need for additional revenue streams for AD facilities was urgent to help projects pencil out. Joblin and Sniegocki recognized the value of the fibers coming out of digesters, but had witnessed various product development initiatives go awry. "While we knew we couldn't finance a digester project based on revenues from fiber products, it can be the difference between a successful project and one that is not," notes Joblin. "We believed that we needed to develop a value-added bagged retail product."

Three or four years ago, Cenergy hired consultants to help figure out markets for the digested dairy manure fibers coming out of two large-scale facilities the company had helped develop in Idaho. "They had us talking with various soil products companies, but in the end, it was all for naught and we didn't move ahead," says Joblin. "Then one night, Ted and I sketched out what we wanted to do on the back of a cocktail napkin, and decided to develop a product on our own. The end result is Magic Dirt™, a bagged potting soil that has been certified as 100 percent biobased by the USDA's BioPreferred Program and approved for use in organic production by the Idaho Department of Agriculture." The product is also certified as a premium potting soil by the Mulch and Soil Council.

Magic Dirt, introduced in the spring of 2014, is a blend of nutrient-rich digested manure and other recycled natural materials that has a pH within the 6-7 range and a guaranteed analysis of 1.15% Total N, 0.30% available phosphate and 0.35% soluble potash. According to Joblin, that is "6- to 10-times the nutrients found in other brands of premium potting soil." It is packaged in 1 cu.ft. bags and distributed to garden centers and big box retailers in Idaho and parts of Utah, Oregon and Washington State. "Our blend is like peat moss with natural nutrients," notes Sniegocki. "There is a big push not to use peat moss because of the significant greenhouse gas emissions — both carbon and methane — associated with its harvesting. For every acre harvested, 2,400 tons of methane are released." In its marketing materials, Cenergy also points out that every cubic yard of Magic Dirt "is the by-product of generating more than 100 kWh of renewable energy" and offsets methane by avoiding peat harvest. (Cenergy does not factor in methane avoidance resulting from anaerobic digestion of dairy manure.)

Another driving market factor is the continuing growth of gardening in the U.S. According to market research conducted by the Garden Writers Association over a 3-year period (2010-2013), of the 164 million homeowners in the U.S., nearly half gardened in the past 12 months and on average, spent $530 to $615/year on lawn and garden products. "The study also found that 25 percent of gardening homeowners are likely to pay more for ecofriendly products such as Magic Dirt," says Joblin.

Cenergy has found that the DVO digester technology (top) is the most effective system for removing volatile solids and yielding long, linked fibers after solids separation (left, right). The fibers give Magic Dirt the porosity and water holding capacity that emulates peat moss.

Product Characteristics

Early on in product development, Cenergy determined it needed to use dewatered fibers from DVO, Inc.'s patented Two-Stage Mixed Plug Flow™ digester systems. "From our vantage point, the DVO digester technology is the most effective and efficient system for removing volatile solids and yielding long, linked fibers after solids separation," explains Joblin. "The long fibers hold water and give Magic Dirt the porosity that emulates peat moss."

Melissa VanOrnum, DVO's marketing manager, explains that retention time in its dairy digester systems is generally engineered for 22 days. "That gives bacteria time to get the energy out and achieve pathogen kill," she says. "The plug flow aspect of our unique hybrid design yields a guaranteed retention time. And the mixing capability eliminates stratification of the solids and the liquids so that all material is fully digested." DVO utilizes compressed biogas to mix the waste, eliminating the need for moving parts inside the digester. "This reduces O&M costs, as well as the energy required to operate the system," adds VanOrnum. "Our patented mixing system is also much gentler on the long fibers in the waste. Preservation of the long fibers and the more complete digestion of the starches lead to higher quality solids that are more peat-like in appearance."

The digested fibers do not have to go through a composting phase prior to bagging. In the case of the Idaho dairies, only a portion of the separated fibers are used to make Magic Dirt. The remainder is used for bedding at this time. "We are taking it one step at a time because we are learning every step of the way," notes Sniegocki. "One fact we didn't realize starting out is that the product needs to be registered in every state it is sold — as a soil amendment in some states and a fertilizer in others. The Idaho Department of Agriculture has been very supportive of what we are doing, and has helped us with registration in surrounding states."

Blending of the fibers and other ingredients and the bagging of Magic Dirt are contracted out to a company near the Idaho digesters. The product has been analyzed extensively to verify the nutrient claims. And during testing, it was found to hold more than three times its weight in water, an attribute that makes it perform well as a peat alternative.

In April, Magic Dirt was approved as an "Idaho Preferred" product (sourced and manufactured in Idaho), and Cenergy was invited to participate in Idaho Preferred promotions at 25 Walmart stores in Idaho. "Our product had to be in the stores in May," says Sniegocki. "We had to scramble to print the signage, but this was a great opportunity to introduce Magic Dirt."

As the product has been introduced, one question being asked is why Magic Dirt isn't the same price as a bag of composted cow manure, which sells for much less. "That is one of our biggest marketing challenges so far," says Joblin. "People don't understand the base ingredient, and we have to explain that this is a premium potting soil with peat-like attributes. That is one of the reasons we started out with getting the certifications — to distinguish Magic Dirt from other manure-based products available."

Joblin and Sniegocki are interested in working with other digester facilities using the DVO technology, both to produce Magic Dirt as well as explore other product opportunities. Product development is slow in the beginning as a significant amount of fiber testing is needed, along with fine-tuning blends and identifying retail outlets. But the need for the long-term revenue stream outweighs that process.

"We are seeing more AD projects that negotiate a flat rate for their power purchase agreements with utilities," explains Sniegocki. "That rate might be adequate for the first several years, but down the road, costs to maintain and operate the digester, engines, etc. go up, but the power rate is flat. So operators need to have other revenue sources to come in and cover those cost increases they will incur. Products like Magic Dirt may not be a huge piece of revenue, but they will generate enough revenue to equal out inflationary trends. That's why we say added value products can make or break a digester's success."

While in initial product testing in 2013, Cenergy put Magic Dirt through the ultimate growth test, according to Joblin — a ninth grade science fair project. "The student did growth trials with Chinese parsley bedding plants. He used dirt from his mother's flower bed, the leading brand of organic potting soil and Magic Dirt. Each was given equal amounts of water and sunlight. And Magic Dirt performed the best! He earned an A on the project."

Mother Earth News, *Cooking Light* and *American Gardener* magazines are conducting their own Magic Dirt growth tests and will publish results by the end of this summer, he adds. "And Ted and I just finished our pitches to other chains, and it went well. Everyone seemed to like our sustainability story. Because of the market acceptance of Magic Dirt, we will be expanding our production to other states for 2015."

In 2013, Cenergy put its product through the ultimate growth test — a 9th grade science fair project. Trials were done using Chinese parsley, planted in a leading brand of organic potting soil (left), soil from the flower bed of the student's mother (center), and Magic Dirt (right).

You might also like:

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This entry was posted on Tuesday, July 15th, 2014 at 8:46 pm and is filed under Uncategorized. You can follow any responses to this entry through the RSS 2.0 feed. Both comments and pings are currently closed.

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Peat Usage

Peat is purchased in tractor trailer load quantities by very large plant growers at about $27 per cubic yard ($1 per cubic foot). Peat supplies are tightening and peat is increasingly seen as an unsustainable product. Plant growers would switch if performance of the alternative was comparable and did not create additional costs or plant management problems.

Growers use compressed peat (2 to 1) in 55 cu ft bags (110 cu ft of material). Peat is compressed for shipping and storage. Bales are picked up with a fork lift and dumped into a fluffer. Newer equipment will shred a larger bale, 128 cu ft compressed or 256 cu ft loose, and eliminate the fluffer. However, loose material could be processed with the same equipment. Storage is a concern to growers with as much as 1/3 of annual usage, some 500 to 600 pallets, stored outside. 90% of the material is used between March and June.

To package compressed fibers the moisture content of the fiber would need to be reduced from 60 to 40% and could be accomplished by capturing waste heat from the digester. Only one manufacturer of compression packaging equipment was found. At an estimated $1 million, the cost of the system rendered the market infeasible to pursue at this time.

There may be opportunity to provide loose product to smaller growers. A least cost approach (perhaps about $20,000) to packaging would be to blow fibers into a hopper attached to a filling machine and loosely pack in Super Bags. Without compression, these bags would not be stackable and would have to be stored undercover to prevent concentration of nutrients, another significant expense.

Estimated Farm ADDF:
* 800 cows (712 lactating and 88 dry) = 5,550,920 pounds of dry matter manure solids.
* Digestate at 60% dry matter = 9,251,533 pounds of fiber (4,625 tons).
* At 945 pounds per cubic yard (at 60% DM) this equates to 9,790 cubic yards produced.
Measured in 15-yard dump trucks = 653 loads.

Estimated peat usage:

USGS data for Peat production and consumption indicate that U.S. peat consumption averaged 1,410,000 metric tons (1,579,200 short tons) per year for the period 2010 to 2014. Imports, largely from Canada, accounted for over 60% of consumption. Most U.S. production is reed-sedge peat, while imports are sphagnum peat. Sphagnum peat is more desirable for potting mixes.

A large greenhouse operation in CT (18 acres under cover, 20 acres outdoor seasonal production) reported using approximately 16,000 cubic yards of compressed sphagnum peat for the 2015 growing season. They blend their own potting mix containing about 80% peat.

Research Quality Assurance for Anaerobically Digested Dairy Fiber (ADDF)
1. Experimental design and statistical analysis: Trials will be designed to provide adequate replication and appropriate controls for treatment variables. The number of replicates for plant growth trials should be sufficient to determine if a 25% difference in size between treatments and controls is statistically significant. Depending on species, variables such as shoot fresh weight, stem caliper and plant height and width will be used to evaluate plant growth responses. Non-destructive measurements will be used primarily to allow repeated measures. Blocking should be used where appropriate to account for gradients in the growing environment. A commercial potting mix or equivalent that does not contain ADDF will be used as a control for comparing experimental formulations.

2. Data acquisition: Accurate and precise measurements are critical to useful results. Given the inherent variability in plant growth, measurements of dimensions such as height or caliper will be as consistent as possible among experimental units. Shoot fresh weight will be measured at the conclusion of experiments when possible. Subjective evaluations such as degree of floral development will be documented with clearly defined criteria, for example the garden mum maturity stages published by Syngenta. Well-documented published procedures (e.g., *Standard Methods for Examination of Water* or *Recommended Soil Testing Procedures for the Northeastern United States*) will be used for extracting growing media and measurement of pH, electrical conductivity and nutrient ions. pH and EC will be measured to 2 or 3 significant digits. Meters and analytical instruments will be calibrated regularly according to manufacturer's directions. Colorimetric analyses will be used to measure ammonium, nitrate and phosphate in potting mix extracts. Standard curves will include at least 4 concentrations to insure linearity, with a miniumum coefficient of determination (r-square value) of 95%

3. Data analysis and interpretation: Data will be analyzed using Statistical Analysis System software (SAS Institute, Cary, NC). Appropriate statistical models will be applied, primarily Analysis of Variance using PROC ANOVA for balanced designs, depending on the structure of the data set. Single-degree-of-freedom linear contrasts will be used to evaluate preplanned comparisons, e.g., media containing different amendments. Tukey's HSD will be used for mean comparisons.

Supporting documentation (see also the Fianl report Narrative and Lamont MS thesis, Chapter 1 in the Apendix.

1. Example: Garden Mum Study
Objective
- Evaluate ADDF media for garden mum production
- Evaluate nutrient supply from ADDF under field conditions

Procedures
- Crop & culture
- Garden mums
  - variety Hankie Yellow
    - yellow daisy
    - late season, expected maturity week 39 – 40 ship week 26
- 8” pans (Dillen 8 x 5 Mum Pan, 2.88 L capacity)
- 1 cutting per pot
- No pinch
- Natural season
- Outdoors on ground covered with fabric weed barrier
- Drip irrigation using Netafilm multi-outlet drippers (MOD)
- Constant Liquid Feed - fertilize at every irrigation with Plantex 19-2-19 at 0.5 g/L; inject with

Dosatron fertilizer proportioner

Treatments

- Control: Fafard 1-P (commercial mix, 80% Peat:20% Perlite)
- 2 Peat:2 ADDF:1 Perlite
- Peat:ADDF:Rice Hulls
- Coir:ADDF:Perlite
- Coir:ADDF:Rice Hulls

Exptl design / replication

- 5 trts (mixes)
- 24 plants/trt
- Randomized complete blocks; 6 blocks, 4 plants/block/trt (4 plants of same treatment per MOD)

Data to obtain

- physical properties of mixes including water holding capacity and porosity (send to JR Peters lab for porometer test)
- initial SME of mixes (our extract; pH, EC, NH4, NO3, PO4 in our lab, send to UConn Soil Testing for Ca, Mg, K, micronutrients)
- Pour-thru extracts at 2 week intervals
- Plant tissue analysis mid-crop (median mature leaves)
- Final plant size (Height & width)
- Final aboveground fresh weight

Potting mix preparation

- add gypsum at 2 g / L to to ADDF mixes to supply Ca and counteract alkalinity
- 24 pots * 3 L/pot = 72 L each mix, make 90 L to allow for mixing loss, etc
  - Use soil mixer, 3 - 5 minutes per batch
  - Check pH in saturated slurry prior to planting, should be 5.5 to 6.5 adjust if necessary using dolomitic lime at 1 - 2 g/L to increase, elemental sulfur at 1-2 g/L to decrease

2. TESTING pH and EC IN GREENHOUSE POTTING MIXES

A. SOLUTION DISPLACEMENT ("POURTHRU") MEDIA EXTRACTION
ref: Wright, R. D. The Virginia Tech Extraction Method
see also: www2.ncsu.edu/unity/lockers/project/hortsublab/index.html

MATERIALS

1. Plastic "saucers" with ridges
2. Deionized water
3. Disposable cups
4. pH meter and electrodes (standardized per manufacturer's instructions)
5. Conductivity meter (standardized per manufacturer's instructions)
6. Newspaper or paper towels

PROCEDURE

1. Thirty minutes to one hour before the extraction, irrigate the pots that will be extracted. Irrigate per normal procedures. Allow time for excess water to drain out of the pot and for the growing medium to equilibrate.
2. "Blot" the bottom of the pots on newspaper or paper towels.
3. Label 5 oz disposable cups with sample identification.
4. Place the pot in a saucer and pour, slowly and evenly, a measured amount of displacing solution

(deionized water is generally recommended) over the surface of the medium. See Table 1 for recommended volumes. Collect the leachate in the saucer. If insufficient leachate is collected, repeat the application of displacing solution. The volume of leachate required will depend on the instruments used for pH and EC measurements. For the Cardy EC and pH meters, 15 milliliters (1 fluid ounce) will suffice. The extract does not need to be filtered unless additional assays are to be conducted.

5. Transfer the leachate to a labeled cup.
6. Measure the pH of the extract. Using the Cardy Twin pH meter, pour 2 successive aliquouts of extract onto the electrode, using the first as a rinse for the previous standard or sample.
7. Measure the conductivity (EC) of the extract. Using the Cardy Twin EC meter, pour 2 successive aliquouts of extract onto the electrode, using the first as a rinse for the previous standard or sample.

Table 1. Amount of water required to displace approximately 50 mL in various containers.	
Container size	mL
4 to 6 inch	75
6 ½ inch	100
1 qt	75
4 qt	150
12 qt	350

B. SATURATED MEDIA EXTRACT

ref: Warncke, D. in: Recommended soil testing procedures for the northeastern United States. Northeastern Regional Publication Bulletin 493.

APPARATUS / MATERIALS

1. Beaker (5 to 12 oz plastic disposable cups, depending on sample size)
2. Spatula (plastic potting labels are a good disposable substitute)
3. pH meter
4. Conductivity meter
5. Deionized water

PROCEDURE

1. Label a disposable cup with sample identification.
2. Fill the cup with a sample of potting mix.
3. Prepare a saturated medium sample as follows:
    a. Gradually add distilled water while mixing with a spatula, until the sample is just saturated. At saturation, the sample will glisten, a thin film of free water will be present on the surface, and water will flow when the container is tipped. If the sample is too wet, add potting mix in small increments.
    b. Let the sample equilibrate for 30 minutes, then recheck for saturation. If the sample has stiffened, add a minimal amount of water and allow an additional 15 minutes equilibration.
4. Depending on the instruments available, pH may be measured directly in the saturated slurry or in an extract. EC measurements must be made with an extract. To obtain an extract, the solution phase may be simply decanted from the sample. To obtain a larger volume and at the same time clean up the sample for additional assays, the aqueous phase may be extracted under vacuum with a Buchner filter funnel.
5. Measure the pH of the slurry or extract as described for the PourThru extact.

6. Measure the conductivity of the extract as described for the PourThru extact.

3. NITRATE DETERMINATION WITH SALICYLIC ACID

Ref. Cataldo, D.A., M. Haroon, L.E. Schrader, V.L. Youngs. 1975. Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. Commun Soil Sci Plant Anal 6:71-80

I. Reagents:

A. 5 g salicylic acid in 100 mL conc H_2SO_4. Make up in storage bottle to avoid transfer. Measure 100 mL H_2SO_4 in a glass cylinder or beaker. Transfer about half the acid to a storage bottle containing a stir bar. Put the bottle on a stir plate. Use a powder funnel to add the salicylic acid while stirring. Add remaining H_2SO_4 after salicylate begins to dissolve. Refrigerate.

B. 2 N NaOH (160 g NaOH / 2 L). Measure 2 L of water and add to an erlenmyer flask. Add a stir bar and place on a stir plate. Add NaOH to water slowly, while stirring. Let cool before using. Transfer to a storage bottle that can be capped. Don't use a ground glass stopper.

II. Apparatus

A. Transfer pipet,0.1 mL
B. 0.4 mL dispensor (e.g, Eppendorf RePeater)
C. 10 mL dispensor (e.g., Brinkmann Dispensette)
D. 20 mL glass scintillation vials or 12 mL glass test tubes
D. Spectrophotometer capable of reading at 410 nm

III. Standard Procedure:

1. Pipet 0.1 mL sample aliquot containing approximately 1 to 20 ug NO_3-N (i.e., 10 to 200 ppm NO_3-N) into the test tube or vial[z]
2. Add to 0.4 mL reagent A, swirling gently to mix
3. Let stand 20 min
4. Slowly add 10 mL NaOH
5. Let cool to room temperature
6. Read absorbance at 410 nm[y]

III. Standard Curve:

1. Primary standard 1000 ppm $NaNO_3$
2. Working standards: 0, 50, 100, 150, 200 ppm NO_3 - N
3. Duplicate standards for standard curve.
4. Use linear regression to calculate concentration as a function of absorbance. Reagent blank should be less than 0.005 A. R^2 should be 95% or greater.

IV. Notes:

Larger samples, e.g., 0.5 mL can be used by drying the solution overnight in an oven at 80 C

Add 0.1 mL H_2O to re-dissolve the sample prior to adding reagent A.

If the absorbance of a sample is greater than the standard curve (specified as 95%, typically 99%), simply dilute the colored solution by an appropriate factor to obtain absorbance within the curve and reread. Formation of the nitrosalicylic acid is complete to at least tenfold higher than the linear range of the standard curve.

H_2SO_4-SA volume should be about 4 times the sample volume

NaOH volume should be about 25 times the acid volume

Nitrite at 1.5 mM does not interfere. Higher concentrations have not been tested.

Method has been evaluated for aqueous extracts of potting mixes and plant tissue. Other extractants or sample types should be evaluated with known additions to insure linearity.

Twilight Workshop

CLIMATE ADAPTATION & NUTRIENT MANAGEMENT
STRATEGIES FOR CONNECTICUT FARMS

Nutrient Removal Strategy: Learn how a recent study performed by the Cooperative Development Institute in partnership with CT Resource Conservation & Development can convert dairy manure into fibers that can be used to create greenhouse & nursery industry growing media. Explore the potential these findings have for your dairy farm or greenhouse/nursery operation.

Exploring Climate Extremes: Attendees will have a chance to explore and share strategies to help farms cope with the challenges of climate change associated with drought, heat stress, excessive moisture, longer growing seasons, unpredictable weather, and changes in pest pressure. Current examples and techniques from around the State will be discussed.

Adaptation Strategies for CT Agriculture: Participants will learn about State and Federal programs that can help them adapt, including conservation programs, risk management tools, and crop insurance products.

September 29, 2015 5:30-7:30pm

Connecticut Farm Bureau Office
775 Bloomfield Ave, Windsor, CT 06095

Free to attend, advance registration is requested. To register or for questions please contact CT RC&D at 860-345-3977

American Farmland Trust · Connecticut Department of Agriculture · Connecticut Farm Bureau · RC&D Connecticut · USDA United States Department of Agriculture Risk Management Agency · UCONN College of Agriculture, Health and Natural Resources Extension

This institution is an equal opportunity provider.

The Climate Change Program is a cooperative effort of American Farmland Trust, the University of Connecticut Cooperative Extension System, the Connecticut Department of Agriculture, and the Risk Management Agency/USDA
The Nutrient Removal Strategy Program is a cooperative effort of Connecticut Resource Conservation & Development, CT Department of Energy and Environmental Protection and The Cooperative Development Institute

APPENDIX 11