Development of Alternative and Sustainable Substrates for Container Nursery Crops

Principal Investigators:
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Project Objectives:
The long term goal of this project is to identify and develop regional and sustainable sources of horticultural substrates for the nursery industry. Recent instability in fuel costs have caused tremendous price increases and reduced availability of bark. Added to this, the decline in housing and construction has contributed to a decline in domestic forest operations which in turn have led to a decline in bark supply. Objectives are to develop alternative substrates from three different broad sources: 1) currently underutilized and/or waste biomasses (logging slash, forest residuals, corn stover, cotton stalks); 2) biomass generated from statewide efforts to remove invasive plant species (Eastern red cedar); or 3) biofuel crops that can be grown and harvested specifically as a substrate (willow, switchgrass, giant miscanthus). Once substrates are indentified, Best Management Practice Guides will be developed, demonstrated, and disseminated to stakeholders.

Our team’s approach for developing new substrates is a four-phase process. First, materials are identified that might be used a substrates on a regional basis in each of our respective regions. Actual availability and potential cost for securing these materials are investigated with the help of local experts (agriculture economists, forestry consultants, etc.). Potential of using these materials on a cross-regional basis is also discussed amongst our group (we are currently exploring the idea of using bamboo biomass as a substrate in all of our regions). Some materials may have a limited range of utility (for example invasive red cedar in the Kansas region or reed-sedge peat in the upper Midwest region).

The second phase of the investigation involves taking the material from its parent form and processing it into a usable substrate. Once materials are identified and secured, their initial processing, particle size reduction, storage, and base physical properties are measured. Organic materials respond differently to processing (chipping and hammermilling), thus a range of processes must be explored to determine which combination of processes results in a substrate with suitable particle properties that would facilitate potting operations at a nursery and provide an ideal environment for plant growth.

The third phase of the process involves observation of the materials in the container. Our current process is to use fast-growing herbaceous crops to quickly ascertain how the substrates interact with common fertilizers and amendments typically used by nursery producers. These factors would include substrate pH, physical properties, development of nuisance organisms (mushrooms, algae, weeds, etc.) in the substrate, insect or disease problems, and overall plant performance. By analyzing foliar nutrient content, we can quickly ascertain the effect these materials have on overall plant nutrition and whether or not special nutrient supplements are necessary.
The fourth phase is to determine the suitability of these materials over a period of 4 to 12 months, which is the typical production cycle for woody nursery crops. All materials evaluated to date have lower lignin content than pine bark. Lignin is a complex polymer that binds to cellulose fibers to strengthen and harden plant cell walls. It is thought that the lesser the lignin content, the less stable the material will be in the container environment. Thus changes in substrate physical properties over time is the primary concern during this phase of evaluation.

**ACCOMPLISHMENTS:**

This is a relatively new project and has been assigned to faculty that have taken new positions at their respective institutions. Accomplishments in this project can categorized two ways: 1) development of laboratory facilities needed to conduct the assigned research, and 2) initial findings on the basic chemical, physical, and biological properties of alternative substrates in laboratory and field trials.

**Laboratory development:** Altland had just joined the ARS lab in Wooster, Ohio; Owen needed to update and retrofit his existing facilities to participate in this and another FNRI project; and Boyer was just hired to begin work at Kansas State University. A nursery production site is still being constructed in Wooster, while laboratory facilities have been updated with new equipment for processing of substrates (hammermill, grinder, sieve shaker, etc.), equipment for determining substrate physical properties, and laboratory systems for nitrogen analysis of water and substrate samples. Oregon State University has been updating facilities, including the purchase of a hammer mill, porometers, pressure plates, hanging column system, high pressure liquid chromatography and pH/EC meter to conduct physiochemical characterization of existing and alternative soilless substrates. At Kansas State, Boyer has purchased laboratory equipment including a pH/EC meter, tissue grinder, general lab equipment, hammer mill, soil mixer and conveyor, and a high-capacity forced-air drying oven. She also built a nursery container pad with overhead irrigation.

These funds were spent building and securing facilities and equipment used directly for the assigned research project. These upgrades provide an infrastructure for substrate research that will serve the nursery industry for many years.

**Assigned research.** We have many research accomplishments. Most of this research has been under the first three phases described above: identifying potential alternative source materials for substrates, understanding the necessary processing steps required to convert source materials into a usable substrate, and observation of short-term crops growing in newly developed substrates. Thus far, our team has been working with the following plant biomass sources: switchgrass (*Panicum virgatum*), willow (*Salix* spp.), corn (*Zea mays*) stover, giant miscanthus (*Miscanthus × giganteus*), poplar (*Populus* spp.), bamboo (*Phyllostachys* spp.), and eastern red cedar (*Juniperus virginiana*).

All of the above listed materials have higher pH than pine or Douglas fir bark. Amendment with peat moss or compost at rates typical of nursery producers (varies by region) lowers pH in alternative substrates to a more moderate level (6.0 to 6.5). However, this has led us to eliminate lime from the fertility package, as pH is already at the upper end of the ideal range. In some
early plant trials, we have documented nutrient deficiencies in calcium (Ca) and magnesium (Mg) as a result of lime omissions. We have also observed iron (Fe) deficiencies in some substrates, despite addition of a general micronutrient package. We are currently working with sulfate and oxide forms of Ca, Mg, and Fe as fertilizer supplements to avoid deficiencies manifesting in plants.

We have found that materials processed through a hammermill equipped with a 3/8-inch screen produces substrates with particle size distribution similar to bark substrates currently used. Despite similarities in particle size distribution, alternative materials tend to hold less water and have greater air space than pine bark. Amendment with sphagnum peat moss and compost decreases air space and increases water holding capacity to levels considered more ideal, and to levels similar to pine bark. Despite similar physical properties (a static measurement), water use efficiency for alternative substrates may still be lower. Addition of hybrid poplar incrementally decreased water use efficiency (7 g/mL).

We are also studying nitrogen (N) dynamics in the alternative substrates. One of the initial concerns with all the aforementioned alternative substrates was N immobilization. As these substrates are probably more easily decomposed than pine or Douglas fir bark, they are also more likely to immobilize N to aid in the decomposition process. We have observed slow initial growth of some plants in alternative substrates compared to pine bark, however, after 6 to 8 weeks plants in alternative substrates had ‘caught up’ and outperform those in pine bark. We attribute this to temporary immobilization and subsequent release of N in alternative substrate materials. To eliminate the initial stunting of crops in alternative substrates, we are evaluating fertilizer application techniques that would turn this phenomena from a disadvantage to an advantage. We are currently evaluating how dibbling controlled release fertilizers (placement of the fertilizer beneath the liner rootball at the time of potting) can alleviate N immobilization. We found that dibbling fertilizers in switchgrass substrates resulted in similar or superior growth to all application methods in pine bark substrates. Furthermore, switchgrass substrates are leaching less N compared to pine bark, regardless of fertilizer rate or application method. The implication is that with a simple modification of fertilizer application technique, plants can be grown in alternative substrates with no initial stunting and greater levels of retained N (greatly reduced N leaching).

A great deal of other research is being conducted concurrently to evaluate pH amendments, plant susceptibility to pathogens in alternative substrates, silicon (Si) availability from alternative substrates, water and nitrogen use efficiency, herbicide efficacy and phytotoxicity with alternative substrates, and others.

Our immediate goal now is to identify two or three materials with the greatest potential for use in the nursery industry, and focus our efforts on those materials to better understand how they react in the vast and complex environments typical of nurseries throughout North America.

TECHNOLOGY TRANSFER/IMPACT:
Our project has only recently begun and has had little industry impacts thus far; however we have made great strides toward identifying and characterizing a number of soilless substrates that
show real industry promise. Our group maintains close ties to the industry stakeholders to ensure we are staying ‘on-track’ to create realistic and cost effective solutions that can implemented in existing nurseries. We have begun our initial evaluations of cedar, switchgrass, and hybrid poplar to find promising results. In addition, we have identified some of the cultural management practices (water management and fertilization) that may need to be altered to ensure success with each of these substrates. Rigorous research will continue in the lab as well as on-farm nursery field evaluations to look at all aspects of each substrate alternative.

To date, we have submitted three manuscripts to peer-reviewed journals, with three more being prepared for publication by year’s end. An article was also submitted to a widely distributed trade magazine to disseminate our research efforts to a wider audience. We have presented this research at several nursery trade show and workshops throughout each region. We are presenting our data to our peers and stakeholders as we accumulate it, with the intent of using their criticisms, critiques, and comments to focus and steer our future research.

**COLLABORATORS:**
Charles Krause, USDA-ARS, Wooster, Ohio; James Locke, USDA-ARS, Toledo, Ohio; Bill Hendricks, Klyn Nursery, Perry, Ohio; Dick Posey, Buckeye Resources; Heather Stoven, Oregon State University; Sam Doane, J. Frank Schmidt and Son Co.; Wade Pruett, Phillips Soil Products, Inc.; Ross Dumdi, Bailey Nursery, Inc.; Ned Jaquith; Bamboo Garden Nursery; Dan Sullivan, Oregon State University; Jason Griffin, Kansas State University; Zachariah Starr, Kansas State University; and Stuart Warren, Kansas State University.

**ADDITIONAL FUNDING/EXTERNAL SUPPORT:**
As part of a larger multistate, trans-disciplinary team of scientists, we applied for multi-million-dollar USDA CREES Specialty Crops Research Initiative CAP grant in 2008 and 2009. Both of those applications received high ratings, although they were ultimately not funded. We are planning to submit our application again in 2010.

In the Pacific Northwest, we have received $4,750 from industry and hope to receive additional dollars from J Frank Schmidt Charitable foundation and Oregon Department of Agriculture (not shown) to initiate evaluations of culled shade tree and bamboo this fall/winter.

Clockwise: A stand of hybrid poplars in an Oregon plantation, a bamboo grove in northern Ohio, switchgrass growing in western Pennsylvania, and a crop of butterfly bush growing in substrates composed either of switchgrass or pine bark.