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Alternative Containers for a Sustainable Greenhouse and Nursery Crop Production

With the ever-increasing customer demand for sustainable greenhouse and nursery products, many growers are exploring ways to make their businesses more 'green' – both in terms of environmental impact and public perception. Many consumers view the use of plastic products as an unsustainable practice (Hurley, 2008). Amidon (1994) estimated that the United States used 521 million pounds of plastic in agriculture, of which 66% of the total plastic was used in the nursery industry in the form of containers. In 2002, there were 1.678 billion pounds of plastic used in the agricultural sector (Levitan and Barros, 2003). Even though plastic containers meet the production needs of the nursery and greenhouse industry, plastic derived from petroleum is nonrenewable. Furthermore, used plastic containers are primarily disposed in landfills given limited access to recycling centers, high collection labor costs, chances of chemical contamination, photo degradation, and liability for poorly sanitized containers. Green industry stakeholders have identified the use of biodegradable container alternatives as a way to improve the sustainability of current production systems.

1. Types of Alternative Containers

Alternative containers similar to traditional petrochemical based plastic have been developed for use in nursery and greenhouse production. Alternative containers are classified based on the nature of degradability at the end of production life (Table 1).

1.1. Recycled plastic geotextile

These containers are produced from recycled plastic bottles that would have ended up in a landfill. The used bottles are turned into a liquid and blended with biodegradable natural fibers, such as cotton, jute, vegetable fibers or bamboo to create a mixture that when heat pressed bonds to produce a fabric like geotextile that is sewn into a container to grow plants. These containers are not biodegradable or compostable but will slowly disintegrate to a point that leaves behind a much reduced carbon footprint. An example of this type of product is the Root Pouch™.

1.2. Compostable

The containers are intended to be separated from the plant at planting and composted separately as they are not quickly or completely biodegradable in the landscape. Most bioplastics as well as hard rice hull and thick-walled paper/fiber containers intended for production of long term crops fall into this category. To further complicate this category some materials are only industrially compostable as they need specific environmental conditions to permit or hasten degradation process. Industrially compostable containers may not break down in a typical backyard compost pile due to the low and inconsistent temperatures, moisture, pH, aeration and microbial populations. ASTM D6400 is the main standard developed by American Society for Testing and Materials (ASTM) for certification of industrially compostable plastics in the United States (ASTM, 2004). It requires a biopolymer to disintegrate to a threshold of 60% biodegradation within 90 days at or above 140° F to be considered as compostable.

1.3. Plantable

The containers are intended to be planted in the soil together with the plant. These containers are intended for short term pre-production and are expected to reduce transplanting shock, save transplanting time and cost, as well as to avoid used container disposal. For these products to live up to these claims, it is imperative that the containers do in fact break down quickly once planted into the soil to allow rooting into surrounding soil and not require removal when the bed is replanted. The rate of container biodegradation following planting depends on the container material, nitrogen, moisture, temperature, pH, microbes, etc. of the soil in which the containers are planted. Scientists are beginning to study the longevity of containers during production and degradation of biocontainers following planting in landscapes. In a landscape trial, using five biocontainer types none completely degraded 8 weeks after planting (Evans et al., 2010). The highest container decomposition was found with CowPot™, which has cellulose and nitrogen from dairy manure. More moderate degradation was found for peat, rice straw and wood pulp containers, The lowest level of decomposition observed during the trial period was associated with coconut fiber containers due to their high lignin content. In a CfAHR(Center for Applied Horticultural Research) study (2009) using tomato plants reported fastest degradation of CowPot™ and DOTPots™ in soil compared to paper and coir containers. For annual landscapes these data suggests that the containers would need to be removed or manually broken apart and incorporated into the soil before the bed can be replanted (Taylor et al., 2010). Slow container degradation could cause root circling resulting in restricted water and nutrient movement and ability to adequately anchor (Appleton, 1993) woody perennials.

2. **Sources of Alternative containers**

Alternative containers are made from a variety of natural materials. These containers have positive environmental impact because they are generally made from renewable, recycled or waste products and they can significantly reduce landfill waste.

2.1. Pressed Fiber

There are a wide variety of hot-pressed fiber containers available on the market. These are constructed from fibrous materials such as rice hulls, wheat, peat, wood pulp, spruce fibers, coir (coconut fiber), rice straw, bamboo or mixed with composted cow manure. Fiber containers are semi porous and promote water and air exchange between the rooting substrate and surroundings. The containers may be biodegradable or compostable. Some include a natural or synthetic binding material such as resins, glue, wax, latex and even cow manure. Other containers rely on the material itself to provide structural stability and extended life span for long term use. Pressed fiber containers tend to have varying degrees of rigidity, material strength, and decay resistance. Unlike plastic, which provides relatively consistent performance in a mechanized production system, the resiliency of pressed fiber containers may depend on the container material, material moisture content, binder, irrigation practices, plant rooting pattern, and time in production. Also, some types of fiber containers weigh significantly more than a thin walled plastic container – especially when saturated.

2.2. Bioplastics

Bioplastics perform just like traditional plastics and are created from either biopolymers or a blend of bio and petrochemical based polymers. Bio based plastics are obtained using renewable raw materials such as starch or cellulose from organic feed stocks: corn, potato, cassava, sugarcane, palm fiber, beet, proteins from soybean or keratin from waste poultry feather, and lipids from plant oils and animal fats and are usually blended with fossil fuel-based polymers to reduce cost and/or enhance performance (Ezio et al., 2011). Petrochemical-based polymers are derived from petrochemical refining. There are 3 main types of bioplastics currently available on the market. (a) Starch-based plastics are water soluble so starch blends are produced by linking 20 to 80% of starch with either bio based or fossil fuel based polymers to improve their physical and chemical characteristics. (b) Poly lactic acid (PLA) produced by anaerobic fermentation of feedstock is mainly used with starch blends due to their slow biodegradability in soil and (c) poly-3-hydroxybutyrate (PHB) made from fermentation of organic feed stocks that are completely biodegradable. They can be processed easily on equipment designed for petrochemicals eliminating the need to develop new industrial machinery. The advantages of biopolymers are their physical properties including weight, structural stability, rigidity and resistance to decay being the most similar to traditional plastics are allowing them to be easily integrated into a wide variety of production systems involving both short term and long term crops. Most of the bioplastic containers are intended to be composted or anaerobically digested at the end of plant production. Some containers such as the SoilWrap^{TM} made from polyhydroxyalkanoate will degrade in the soils and have been incorporated into the design of plantable pots.

2.3. Sleeves

There are several types of containers available in small sizes that are simply growing substrate wrapped in a paper, fiber, or bioplastic sleeve. These are not true containers as they must be kept in a tray until the plant's roots hold the substrate together. These are often paper containers, which are plantable and fully degrade in a single season in the central and southern states. Further north, they may persist for over a year. Examples of commercially available sleeves include Ellepot^{TM} made from paper and SoilWrap^{TM} made from bioplastics.

3. **Impact of Alternative Containers on Plant Production**

The impacts of biocontainer use during ornamental crop production are largely unknown at this time. This section summarizes the current knowledge and potential issues associated with production and post-production impacts of biocontainer use.

3.1. Plant Growth and Development.

Studies so far have not found any significant negative impact of biocontainers on plant growth and development during production or during establishment into the landscape. A study conducted at the US Center for Applied Horticulture Research in Vista, California (CfAHR, 2010) indicated that Petunia grown in SoilWrap and NetPots resulted in plants that were bigger than plants grown in plastic pots whereas plants grown in OP47 BioPots, coir and plastic pots were similar in size and the number of flowers was very similar among the plants in different container types during pre and post production phases. CfAHR (2009) tested tomato growth in four types of biocontainers, DOTPot^{TM}, decomposed cow manure, paper pulp pots and coconut coir pots and compared them to plant growth in black plastic pots and found that the plants grown in plastic containers were heavier than others and the roots grew out of all the biocontainers except coir containers in a week. In contrast there was no effect on root or shoot dry weight of geranium and vinca plants produced and planted in peat or feather containers compared to transplants from plastic containers following six weeks in simulated field conditions

(Evans and Hensley, 2004). Preliminary results from a three month study showed no negative impact of plantable containers such as Soil Wrap^R, Ellepot^{TM} and slotted rice hull on the shoot and root development of two sedum species and liriope during the production period or during field establishment (Ingram and Nambuthiri, 2011).

3.2. Water Use

Due to the semi-porous nature of some biocontainer materials, water may be lost through the container side wall during plant production. The average water use of *Euonymus fortunei* plants grown in one gallon paper and wood pulp containers were 3 to 5 times higher than the standard plastic containers in Michigan based on a four month outdoor study (Wang et al., 2012). The highest rate of sidewall water loss was for peat, wood fiber and manure, followed by coir, rice straw, slotted rice hull, and the lowest sidewall evaporation was observed for bioplastic, solid rice hull and plastic containers (Nambuthiri et al., 2011). The increased drying rate in the fiber containers could mean increased and frequent water requirement for plants grown in these containers compared to plastic containers. A recent study found that the amount of water required producing a 4" geranium ranged from 0.55 gallons per container in plastic containers to 1.1 gallons in the wood fiber containers (Taylor, et al., 2010). The environmental benefits of using biocontainers would need to be weighed against increased water usage dependent upon the water demand of the crop, weather and cultural practices. Additionally, water loss in some of the smaller containers may be partially negated through the use of a shuttle tray.

3.3. Substrate temperature

The importance of keeping substrate temperature below 100°F (37.8°C) to avoid root injury is well documented (Kramer, 1949). However, during warmer months in the southeastern states it is common for the substrate temperature in black walled plastic containers to exceed 107.5°F (42°C) for several hours (Ruter and Ingram, 1990). Porous containers (clay, paper, peat, etc.) showed a slower increase in root zone temperature than non-porous (plastic, glass, paraffin protected, etc.) containers due to a higher latent heat for vaporization of water (Jones, 1931). A lab study reported higher substrate temperature in plastic, bioplastic and soild rice hull containers compared to lower heat buildup in decomposed cow manure, wood fiber pot, coir, peat, rice straw and slotted rice hull containers (Nambuthiri et al., 2011). Fiber containers were found to improve plant production, survival and quality by moderating the substrate temperature of 'Otto Luyken' cherry laurel (Ruter, 1999) and *Euonymus fortunei* 'Gold Splash' (Fulcher et al., 2011; Wang et al., 2012).

3.4. Durability of containers

Preliminary research indicates that some biocontainers tended to tear or break during greenhouse production, packaging, shipping, and retailing especially when wet. Evans et al. (2010) compared dry and wet strength in biocontainers. Hard rice hull containers had the highest wet vertical and lateral strengths. Containers composed of fiber or composted manure or peat had lowest wet vertical strength as these containers absorb water into the wall resulting in softening of the container wall and a subsequent reduction in strength. After 14 weeks, most poinsettia plants produced in peat and cow manure containers were not marketable due to loss of integrity or mold and/or algal growth creating a poor appearance (Camberato and Lopez, 2010). The plantable containers could be hence mostly appropriate for bedding plants or vegetables that have short preproduction phase.

3.5. Lifespan

Container life span can be made to vary from a few months to several years to match with the crop production cycle. Most plantable containers would biodegrade in a few months depending on the environmental conditions. Studies are going on to extend the lifespan of biocontainer using various natural or synthetic adhesives, resins, waxes and binding agents which later determine the rate of biodegradability or compostability of the containers. In general, nursery containers last from 1 to 5 years and usually are not quickly biodegradable, but may be compostable.

3.6. Marketing Advantage

Biocontainers can be considerably more expensive and their cost range from 10 to 40% more than their plastic counterparts (Robinson, 2009). This increased cost means that growers must be able to achieve a higher price for plants in biocontainers or reduce production costs for the system to be economically viable. A study was recently conducted to determine the willingness of consumers to pay more for biodegradable containers using experimental auctions in which consumers made purchases (Yue, et al., 2010). This system allowed researchers to determine what the consumers will actually do compared to what they say they will do on a survey. The results revealed that consumers will pay 58¢ more for a geranium in a 4-inch rice hull container, 37¢ more in straw, and 23¢ more in bioplastic containers than one in a traditional black plastic container. During the 2010 National Poinsettia Cultivar Trials at Purdue, customers were willing to pay 50¢ or $1 more for poinsettias grown in hard rice hull, OP-47, molded fiber and coir fiber containers than those grown in plastic containers (Camberato and Lopez, 2010).

4. **Future Prospects**

Clearly there is still much to learn about the impact of alternative containers on plant growth, water use, as well as the economic and environmental consequences along with energy costs associated with these new products. While there are many unknowns, it is certain that the supply of petrochemicals for conventional plastics will continue to increase in price and the public will become more conscious of our impact on the environment so the pressure to reduce plastics use will only increase. Recently alternative containers impregnated with various components such as natural color, slow releasing fertilizers, fungicides, insecticides and plant growth regulators that are released during plant growth are gaining entry to the market and that could enhance the efficiency of the production system. Industry and researchers are continuously working together to develop and fine-tune sustainable alternative containers to suit emerging grower and customer requirements.

Table 1. Examples of plantable and compostable alternative containers those are available in the market and their source material.

Name of Product	Material
Plantable	
Biopot	bamboo fiber
Coir pot	coconut coir fiber
CowPot™	composted cow manure and natural fiber
DOTPots™	spruce fiber, peat moss
Ellepot®	Paper
Fertil Pot	spruce wood fiber and peat moss
Jiffy-Pot®	Peat
Kord Fiber pot	wood and paper
Net Pot™	rice hull
SoilWrap®	Mirel® (biopolymer)
Straw Pot	rice straw
Western Pulp pot	molded wood pulp, recycled paper
Compostable	
Carbon Lite	Starch
Ecotainer	plant starch (PSM)
Kord Fiber Grow	recycled paper or cardboard
Large Pulp Pots	wax permeated wood pulp
TerraShell™Pot	Poly Lactic Acid (biopolymer from corn starch)
Rice hull pot	rice hull
Speedypot	peat and PLA biopolymer wrapper
Wax tough pot	wood and paper coated in wax

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