W 337-B

# BEYOND PLASTIC POTS

## Part 2: Compostable and R³ Containers for Nursery Crop Production

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Part II of this four-part series, "Beyond Plastic Pots," highlights results from recent research on compostable containers and containers made from recycled and/or bio-based plastics, including significant projects conducted in partnership with the University of Tennessee Institute of Agriculture. Growers interested in incorporating alternative containers including compostable, R³ and plantable containers into their production systems will find the information in this series helpful for understanding and comparing plant and container performance and implications of container type on production practices and economics.

## Compostable Containers and Containers Made From Recycled and/or Bio-based Plastic, R³ Containers

*R³ refers to containers made from recycled or bioplastics that can be reused and/or recycled. They are generally not compostable; however, those containing some natural fibers will break down into smaller pieces over time.*

Using compostable and R³ containers, those made from recycled and bio-based plastics, as alternatives to conventional petroleum-based plastic containers was introduced in Part I of "Beyond Plastic Pots," UT Extension Publication "W 337-A: Compostable, Plantable and Other Containers for Nursery Crop Production." In Part II we expand on the economics of using and marketing these containers as well as the impact on fertilization, water use, plant growth, container longevity and compostability. Compostable and R³ containers are similar to traditional petroleum-based plastic containers in terms of requiring removal before the plant is installed in the landscape (Figure 1). However, unlike traditional plastic containers, compostable pots will decompose over time.

Some biocontainers can be torn up and placed in the hole with the plant during installation or placed in a home composting bin, while others require industrial composting to degrade.

*Bio-based plastic containers are containers that are made from plant- or micro-organism-based plastics and generally contain some petroleum-based plastics.*

Some compostable containers appear plantable due to their natural look, whereas others look similar to plastic. Because appearances can be misleading, it is important for the garden center retailer to understand the different containers they market so that they can inform customers on the proper use of the containers. Likewise, it is important that landscape contractors know the container types they are working with and not base decisions on appearance alone. Compostable containers made from molded fiber (recycled paper and/or cardboard [Western Pulp and Kord Fiber Grow] and rice hulls [Rice Pot]) are commercially available and come in a range of shapes and sizes. While most alternative containers are made in the smaller sizes typically used in greenhouse production, molded fiber and rice hull containers are available in larger sizes that are appropriate for nursery production. Other bio-based materials, such as bamboo, soy and poultry feathers, have been used to produce biocontainers and may become commercially available soon.

$R^3$ containers made from post-consumer waste or bioplastics are also available.

Recycled soda and water bottles are combined with plant-based fibers to make fabric containers, such as Root Pouch. Compared to other containers presented in this series, Root Pouch is unique because it is available in large (up to 25 gallons) sizes. Although these containers do not decompose, their natural fibers allow them to degrade into smaller pieces over time. Because they are made from recycled plastic, they are also more eco-friendly than their virgin plastic counterparts. Other containers, such as Jiffy CarbonLite, are made of a mixture of plant-based and petroleum-based plastics and mimic the form and function of plastic containers.

***Figure 1.*** *Compostable fiber container (photo credit: Diana Cochran)*

# Economics

### *Compostable Containers*

Compostable containers are generally attractive to consumers, and the main difference in production cost is the purchase price of the container itself. Of the total cost of production (including the pot, the liner [transplant], the substrate, labor and shipping), a 1-gallon plastic container priced at 40 cents was calculated to be 9 percent in the production of 'Green Velvet' boxwood (*Buxus sempervirens* ×*B. microphylla siebold* var. *koreana*). By switching to a fiber container priced at 62 cents, the cost of production would increase from $4.42 to $4.65, or a 23 cent increase. Although switching to alternative containers may change other factors that contribute to the cost of production, such as substrate volume and fertilizer, the most significant factor is the cost of the container.

Although container cost is a key concern when assessing the economic viability of alternative containers, other notable factors affect the cost of production as well. Because compostable pots are not reusable, nursery producers who typically reuse their containers will assume the expense of buying a new container every time. However, using a new plantable or compostable container eliminates the need for container sanitation and reduces the risk of pathogen contamination.

The different materials used to make alternative containers affect how they fit into the production system. Containers with rough sidewalls tend to stick together, which affects how quickly they can be de-nested. Plantable peat and manure containers take three to five seconds to de-nest, whereas rice hull containers (both compostable and plantable varieties) take about one second — about the same amount of time as for plastic containers. Molded fiber containers have not been tested for de-nesting speed; however, it is likely that they are slower than plastic. Compostable containers are typically stronger than plantable containers, and in some cases stronger than plastic, and lose less water through the sidewalls than plantable containers. Molded fiber containers are porous and absorb water when irrigated, which increases their shipping weight and may lead to higher shipping costs. Furthermore, these containers dry more quickly, which, in addition to increasing their irrigation requirements, results in the substrate drying faster than plastic during transport.

Plants sold in these containers generally bring a price premium, and, therefore, the additional cost can be recouped at the point of sale. As with adopting any new production practice, there is a learning curve, which will likely affect the labor associated with the cost of production; however, this adjustment period is anticipated to be brief.

***Figure 2.*** *Root Pouch (photo credit: Robert Geneve)*

### *$R^3$ Containers (containers made from recycled and bio-based plastic that can be reused or recycled)*

As these containers mimic the form and function of traditional petroleum-based plastic containers, the factors affecting the profitability of these containers are the cost of the container and the price premium they bring at the point of sale. The exception to this is cloth containers, which have similar breathability characteristics and, therefore, similar water usage characteristics, to plantable/compostable containers. Figure 2 shows an example of a cloth container made from recycled plastic by Root Pouch. If these containers deviate from standard container sizes, the amount and thus cost of the fertilizer, substrate, shipping and other inputs to produce each plant changes.

### *Helping the Environment and the Bottom Line*

Consumers are willing to pay a premium price for an environmentally sustainable product, and it is likely that the increased cost of the container can be recouped at the point of sale. Compostable and recycled containers typically do not develop algae and fungal growth that can be common on peat and manure plantable containers, which can lead to a cleaner and generally more attractive plant. Considering that in an experimental auction where real money and product exchanged hands, consumers were willing to pay 58 cents more for chrysanthemums in 4-inch rice hull pots than those in 4-inch plastic containers; recouping an additional 23 cents to produce ‘Green Velvet’ boxwood in a fiber container in the example above should be feasible and in some markets profitable.

# Plant Growth

### *Compostable Containers*

Compostable containers generally have a small positive effect or no effect on plant growth, making them a suitable alternative to plastic containers. The physical properties of compostable containers have the potential to affect plant growth. Porosity and chemical makeup, including their ability to affect substrate pH and provide nutrients to the plants, all provide means of influencing growth. Available container size must also be taken into account, as some compostable containers are not available in the exact size of their plastic counterparts.

Probably the most important factor to consider when switching to compostable containers is their sidewall porosity, which leads to moisture loss and lower substrate temperatures. When substrate temperatures exceed 104 F, plant growth is suppressed and root death can occur. Compostable containers have cooler substrate temperatures due to color and porosity. They are typically lighter in color than traditional black plastic containers and thus absorb less of the sun’s heat. Additionally, their porous sidewalls allow moisture to evaporate and cool the root zone.

Cooler substrate temperatures can be both positive and negative depending on the situation. Climate must be considered when choosing alternative containers. In warmer, southeastern states, using a porous container can prevent roots from being exposed to high temperatures that are harmful to plant health. However, in cooler, northern states, early-season growth may be slowed by cooler substrate temperatures. Substrate temperature in compostable containers remains below air temperature during the heat of the day when root damage is most likely to occur, whereas the temperature of black plastic containers exceeds the air temperature. Keratin, wood pulp fiber (Western Pulp), coir (plantable) and fabric (Root Pouch) containers all had lower substrate temperatures than plastic containers in Texas, Mississippi, Kentucky and Michigan. Keratin, the least porous alternative container, had the highest substrate temperatures among the alternative containers, while the fabric container had the lowest temperature. These trends of lighter, less porous containers (keratin) having higher substrate temperatures than the darker, more porous fabric suggest that evaporation is the main cause of cooling.

Porous sidewalls can also lead to improved growth and survival, especially for woody species that are prone to root rot. In southern Georgia, 'Otto Luyken' laurel plant growth increased 53 percent and survival nearly doubled when grown in a molded fiber (recycled paper) container compared with a plastic #1 (1-gallon) container. The increased growth and survival was attributed to an environment more supportive of root growth — lower temperatures, increased aeration and better drainage. Furthermore, fibrous root development improved in porous containers and was thought to be due to increased air exchange within the growing substrate. Improved root growth may result in better plant performance in the landscape.

Fiber containers can improve the growth of perennials as well. For example, daylily (*Hemerocallis*) had increased growth ('Aztec Gold') or improved appearance and increased number of flowers ('Stella de Oro') compared to those grown in traditional plastic containers. The fiber containers were treated with SpinOut, a copper-based treatment for preventing circling roots and were compared to black plastic containers with and without SpinOut treatment. Untreated fiber containers were not tested. The SpinOut treatment on black plastic containers did not affect growth.

A prototype container made from a 50/50 blend of polylactic acid (PLA — a plant-based material) and soy provides nitrogen to the plants. Initial fertilization is necessary until roots are able to grow toward the container walls and benefit from the released nitrogen. However, these containers have the potential to provide an economic and environmental benefit by reducing the amount of synthetic fertilizer necessary to finish a crop. For example, by using the prototype soy-PLA blend container, marigolds and tomatoes of equal size and quality to ones grown in a plastic container were produced with an 87 percent and 44 percent reduction in fertilizer, respectively. Furthermore, these containers can be broken into pieces and buried near the roots of the plants to release nitrogen as they degrade and result in higher plant performance. Containers made solely with soy-based plastic (not blended with PLA) supply excessive fertilization, which can have a negative effect on plant growth and container longevity. The prototype PLA containers also offer the benefit of pruning roots and reducing root circling due to their chemical makeup.

### *R*$^3$ *Containers*

Plant growth in R$^3$ containers that mimic the form and function of plastic containers is likely to be similar to that in plastic containers. As long as the porous sidewalls of fabric containers are taken into account, plant growth equivalent to that of plants produced in plastic pots can be achieved. In several states, 'Green Velvet' boxwood growth was the same in fabric bags as in plastic pots. However, in Texas, irrigation was based on volume rather than plant water needs, and this resulted in smaller 'Green Velvet' boxwood compared to those grown in plastic. As mentioned above, the porous sidewalls of fabric containers result in evaporation that lowers substrate temperatures more than plastic containers.

# Water Use

### *Compostable Containers*

Plants produced in molded fiber containers with porous sidewalls require additional water to match the growth of plants grown in plastic containers. When the water that is lost through the sidewall is not replaced with additional irrigation, there is a potential for water stress and, as a result, smaller plants.

Generally, pots constructed from solid rice hulls perform similarly to plastic pots in terms of water usage. It is also possible for biocontainers to outperform plastic containers in terms of water use. For example, a study found that keratin containers, a prototype, resulted in lower water use than their plastic counterparts in a nursery setting likely due to their light color and nonporous nature. Vinca water use during greenhouse production was slightly lower when grown in 4-inch solid rice hull containers compared to plastic containers, likely due to the rice hull container's lighter color. However, this slight advantage over plastic was eliminated when containers were placed in shuttle trays, which slightly improved the water usage of both plastic and solid rice hull and eliminated any water usage difference between the two. Shuttle trays (Figure 3) reduced the irrigation requirements of all container types tested; however, the greatest benefits were seen in the more porous plantable containers, which are further discussed in Part III, UT Extension Publication "W 337-C: Plantable Containers for Nursery Crop Production."

Cultural practices can reduce the water losses associated with porous sidewalls, in some cases to the level of plastic pots. For example, in pot-in-pot systems, water requirements and substrate temperature will be comparable to plastic containers. In-ground production insulates the container and protects it from exposure to the sun, therefore reducing the evaporation from the sidewalls and moderating the temperature.

### *R3 Containers*

Many recycled/recyclable containers are made to mimic the form and function of plastic containers and thus do not affect plant water use and growth. Porous fabric containers (Root Pouch) are the exception, as they lose water through the sidewall, resulting in lower substrate temperatures and increased irrigation requirements. When this water loss is replaced through additional irrigation, plant growth is generally not affected.

# Strength and Longevity

### *Compostable Containers*

Most of the compostable containers perform nearly as well as plastic containers under normal production cycles of up to one year. For example, in strength tests, containers made of molded fiber (recycled paper and/or cardboard), keratin and coir fiber retained sufficient strength during a one-year production of 'Green Velvet' boxwood (*Buxus sempervirens* ×*B. microphylla siebold* var. *koreana*) and Dark Knight bluebeard (*Caryopteris* ×*clandonensis*) to be a suitable alternative to plastic containers. Kord Fiber Grow and Western Pulp (both molded fiber-recycled paper and/or cardboard biocontainers) retained strength for a one-year pot-in-pot production of river birch (*Betula nigra*), although after two years roots had penetrated the container bottom (Figure 4). Solid rice hull containers retained sufficient strength after 12 weeks of greenhouse production under overhead irrigation and 15 weeks of ebb-and-flood irrigated greenhouse production. Although untested, solid rice hull containers may be suited for longer production cycles.

Not all compostable containers are created equal; even two containers that are made from the same material can differ in strength. For example, thin-walled fiber containers (1-3mm, ~1/32-1/8 inch) are not suitable for production cycles longer than six months, whereas thick-walled containers (5-6mm, ~1/4 inch) will remain intact. Although the above containers are no longer available, similar results showing the variability in

***Fig. 3***

***Fig. 4***

***Figure 3.*** *Shuttle tray (photo credit: Robert Geneve)*

***Figure 4.*** *Pot degrading after two years in pot-in-pot production (photo credit: Guihong Bi)*

strength are available for containers currently in the marketplace. Tests of two molded fiber containers (recycled paper and/or cardboard) used outdoors in nursery production in Mississippi, Texas and Michigan showed notable differences in strength although both were suitable for nursery production. They generally performed at least as well as plastic containers in terms of strength, and in some locations, substantially better than plastic after 12 months in production. Strength varied by geographic location, indicating that growing conditions (temperature, precipitation, solar radiation, etc.) have an impact on the strength and longevity of biocontainers.

Irrigation amount and frequency influence the strength/longevity of fiber containers because longer saturation results in faster breakdown. Furthermore, ebb-and-flood irrigation is known to weaken biocontainers. Tests conducted on long-term (15 weeks) greenhouse crops found that bioplastic and solid rice hull containers were weakened by the end of the study; however, they were still strong enough to withstand handling and transport and were deemed a viable container for greenhouse production. The absorptive nature can increase the weight and affect shipping costs. Weight of molded fiber containers (#1 size) increases approximately 20 percent when wet.

### *R³ Containers*

Recycled containers or containers made from a mixture of bioplastic and petroleum-based plastic have not been strength tested but will likely perform similarly to conventional plastic containers. Fabric containers are available in a variety of stated strengths from the manufacturer (Root Pouch). Root Pouch containers tested after 15-20 months in production suffered from low tensile strength, suggesting they would likely break during handling after one year in production. This factor highlights the fact that container strength ratings from manufacturers should not be taken at face value. Fabric containers (Root Pouch) have the difficult task of retaining strength during production and then breaking down after the plant is removed. Environmental factors affecting the rate of degradation should be evaluated for use at a given location.

## Home or Industrial Composting?

The terms “biodegradable” and “compostable” mean different things to different people. Although all of the containers listed here as compostable will eventually decompose, their rate of decomposition may be slower than expected. Some biocontainers require industrial composting, necessitating transportation and additional energy consumption. Containers with a home compost option have a lower environmental footprint. For example, two brands of molded fiber containers were found to meet composting standards of 90 percent degradation when ground; however, when cut into 1-cm squares they failed to be compostable after 90 days. Growers and retailers should be aware that some compostable containers may not degrade quickly in a home compost pile.

# Compostable and R$^3$ Containers — Viable Alternatives

Nursery and greenhouse growers interested in increasing the sustainability of their businesses while meeting consumer demands for high-quality, environmentally friendly products have many choices for alternative containers that will meet or exceed the performance of traditional plastic containers. Recent research shows that consumers are willing to pay a price premium for green products and that alternative containers can survive the rigors of production and provide a profitable, high-quality end product to retailers, landscapers and end consumers.

***For general information on alternative containers, see Part I (W 337-A), and for more details on plantable containers, see Part III (W 337-C). For a table format comparison of key features of alternative containers, consult Part IV (W 337-D).***

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