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Cultivating Sustainability: Biodegradable Containers in Horticultural Production

Melanie Hill[a], Emily Stamm, and Paul C. Bartley

101 Funchess Hall, Department of Horticulture, Auburn University, Auburn, AL 36849, USA

mch0097@auburn.edu

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Summary

Plastic containers are the standard in the horticulture industry for the production of plants for retail and landscape use. Sustainability has become a popular topic because the pandemic affected the way people think about sustainability and their impact. The pandemic also created a boom in the plant industry because people were home and had more time to explore their current interests as well as new interests, such as indoor and outdoor gardening. Six containers made from materials other than petroleum-based plastic were used in this study to look at their performance in relation to plastic containers, as well as their degradation and marketability. Plant size, container gravimetric differences from trial initiation to harvest week, container wet and dry tensile strength from trial initiation to harvest week were evaluated; and a consumer opinion survey was conducted at each harvest week. The largest plants were grown in peat and BioPax containers. BioPax containers also had the highest tensile strength at all testing intervals - as wet and dry test pieces.

INTRODUCTION

In the U.S. Horticulture Industry, plastic containers used in the greenhouse and nursery industries amount to more than 750,000 metric tons of plastic (Shrader et al., 2015). Plastic is the standard container type for the horticulture industry because they have a durability that withstands automated production and the strains of shipping, the ease of acquiring many shapes and sizes of containers, and a relatively low cost (Kratsch et al., 2015). However, it is estimated that ~98% of plastic containers are disposed of in landfills due to contamination risks and the cost of cleaning and sanitizing containers (Fuentes et al., 2021; Shrader et al., 2015). In addition to cost-prohibitive factors, containers used in greenhouse and nursery production systems experience degradation due to the light and heat conditions, further disincentivizing container reuse (Fuentes et al., 2021).

Sustainable growing containers fall into one of three categories: plantable, compostable, and bioplastic (Soulliere-Chieppo., 2020). Containers that fall into the plantable category are typically constructed from materials such as coconut coir, manure, peat, paper, and wood pulp and are intended, as the category name implies, to be planted in the soil with the plants still inside them (Soulliere-Chieppo., 2020). Compostable containers have been produced from rice hulls, poultry feathers, recycled paper or cardboard, bamboo, or other fibers and require a home or industrial compost system to be broken down (Soulliere-Chieppo., 2020). Bioplastic containers are made of plastic that started as a plant constituent or has plant constituents instead of petroleum (Soulliere-Chieppo., 2020). Growers prefer bioplastic containers due to their consistency, stability, and durability during handling, processing, and shipping, and similarities to traditional plastic containers. Several sustainable containers are already on the market and have been used in research conducted in greenhouse and landscape settings. Containers previously evaluated include rice straw, rice hulls, paper, peat, coconut coir, composted cow manure, and wood fiber (Conneway, 2013; Kuehny et al., 2011). Results from these investigations varied, but the consensus was that most container types produced plants of marketable size and quality (Kuehny et al., 2011) and that low container strength can be attributed to containers made of coir, wood fiber, peat, manure, and straw (Conneway, 2013).

While some of these sustainable containers are commercially available, an online survey conducted in 2020 found that 83% of horticultural growers do not purchase biodegradable containers (Harris, 2020). Potential reasons for this are that biodegradable containers lack the necessary strength for automation processes and the durability to remain structurally sound for the length of production cycles (Kratsch et al., 2015). If these containers do not maintain structural integrity, then producers risk experiencing losses when containers break during production, shipping, or in the retail environment (Harris, 2020). Since the pandemic, demand for horticultural commodities and sustainably sourced products has increased across horticultural consumers. A study by the University of Georgia found that approximately 1,400 of the 4,200 respondents started gardening in 2020 due to being at home more (Campbell, 2022). Recent market research suggests ornamental plant consumers are willing to pay more for nonplastic and recyclable containers, and an increasing number attempt to avoid the use of plastic or opt for products with packaging that is environmentally friendly (Emmert, 2021; Fulcher et al., 2015).

Considering the variety of plants grown in varying production cycles and changes in consumer appetite, a new investigation into sustainable containers was warranted. This study aimed to evaluate commercially available alternatives to traditional plastic containers in bi-weekly production intervals using crop performance, material testing, and consumer evaluations to determine their viability in floriculture production systems.

MATERIALS AND METHODS

Six biodegradable or biobased containers were evaluated with an industry-standard plastic container through an eight-week basil production cycle (**Table 1**).

Table 1. Biodegradable, biobased, and plastic containers which were assessed in an eight-week greenhouse trial.

Product	Composition	Container size	Image
CowPot	Composted cow manure	5"	
FertilPot	Wood fiber	4”	
EverEco	Tapioca starch	3.5”	
PlantBest	Coconut coir	4.5”	
BioPax	Wood pulp and additives	4"	
Jiffy	Peat	5"	
Control	Plastic	4"	

Eighteen units of each container type were labeled, weighed, filled with a peat-based substrate, and received a basil transplant. Planted containers were randomly arranged on a greenhouse bench. All containers were fertilized once per week (250 ppm of 15N-5P-15K; JR Peters, Allentown, PA) and irrigated with clear water every other day. Four replications from each treatment were randomly selected for harvest every two weeks. Basil plants were cut at the substrate surface at each harvest interval, and fresh and dry weights were recorded. The containers were then dried at 65 C for one week. After the containers were dried, the substrate was removed, and the containers were reweighed to calculate the percentage of weight lost from initiation to the date of harvest.

Tensile strength testing was performed on the containers, both wet and dry, to evaluate changes in material characteristics due to degradation. Harvested containers were cut into rectangular strips (1" in width) and conditioned for at least 40 hours at 23 C ± 2.0 C and 50% relative humidity before tests were run. Dry tests were performed immediately following conditioning. Wet tests were conducted after the samples were submerged in water for 105 min and set to drain for 60 min. Tests began by securing the samples with clamps to the load frame (Series 5565; Instron, Norwood, MA) and concluded when the samples failed (i.e., broke or began to stretch). Each test was performed with the utmost care to ensure sample integrity. However, material integrity changed throughout the study, which resulted in some materials being more fragile than others and, thus, some specimens could not be tested accurately.

At each harvest interval, a survey was conducted to gauge consumer appetite for each container type. Each consumer was polled by age and the frequency of purchasing plants. Only the container, with the plant removed, was revealed to the consumer to survey. Consumers were then asked to rank their likeliness to purchase a plant grown in each container type using a 1-5 scale, where "1" was very unlikely and "5" was very likely.

All data were analyzed via ANOVA with the PROC Glimmix procedure, SAS 9.4 (SAS Institute Inc., Cary, NC). Means were separated using Tukey's honest significant difference (HSD) at a 5% alpha level.

RESULTS AND DISCUSSION

Basil Growth. Basil dry weights were similar across all container types two weeks after transplant **(Fig. 1)**. By Week 4, differences in basil dry weight were observed. Basil growing in coir, plastic, and peat produced the largest plants four weeks after transplant.

Basil grown in EverECO containers, produced from tapioca starches, had the lowest dry weight at Week 4. This trend would continue through Week 6. A significant increase in basil dry weight occurred from Week 4 to Week 6. No differences were observed between container types with the exception of EverECO, which produced the smallest basil.

By Week 8, container effects on basil dry weight differentiated broadly. Peat containers grew basil 25% larger than CowPots and 350% larger than those produced in EverECO. BioPax and plastic containers were the most similar in shape and size.

Dry weights for BioPax and plastic were similar until Week 8. At the final harvest interval, basil grown in plastic containers were 26% larger than those produced in BioPax.

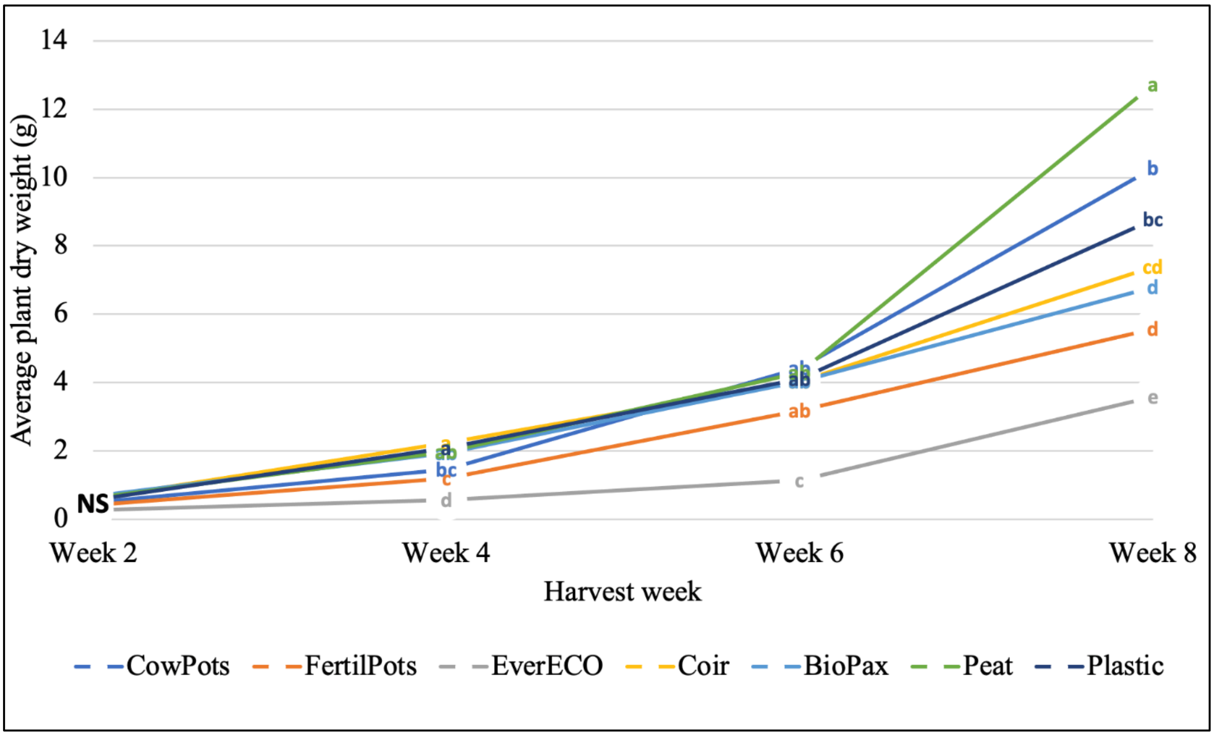

Figure 1: Average plant dry weights for each treatment by harvest date.

Due to volumetric differences between containers, differences in basil growth were likely the result of a more/less restrictive growth environment and may not reflect the characteristics of the materials (**Fig. 2**). Between Week 2 and Week 6, similarities in basil dry weight could be attributed to the containers' stability and volume, which demonstrated only subtle signs of degradation and provided ample space for root growth and development. After Week 6, degradation of the container walls, wetting and drying cycles, and increased resource demand from basil plants could have contributed to the differences observed at the Week 8 harvest interval.

A common challenge with biodegradable plant containers is the evaporation of water through the walls of the container. Some container materials are more porous, reducing plant available water and affecting plant growth. For example, EverECO and wood fiber containers were observed to dry down faster than other containers. Consequently, EverECO and wood fiber containers produced the smallest basil plants on average. The plants grown in peat pots and CowPots were larger than other containers, likely due to the size of the container.

Container Degradation. Degradation can occur rapidly in biodegradable containers (**Fig. 3**). By Week 2, all biodegradable and biobased containers had lost weight. EverECO containers degraded 12.8% by Week 2, but degradation moderately stabilized through Week 6. However, by Week 8, EverECO containers had lost an average of 33.8%. CowPots also degraded quickly and, by the study's conclusion, had lost more than 24% of its initial weight. FertilPots, Coir, BioPax, and Peat containers demonstrated similar degradation rates at each harvest interval. By the conclusion of the study, all container types had lost at least 5% of their original weight.

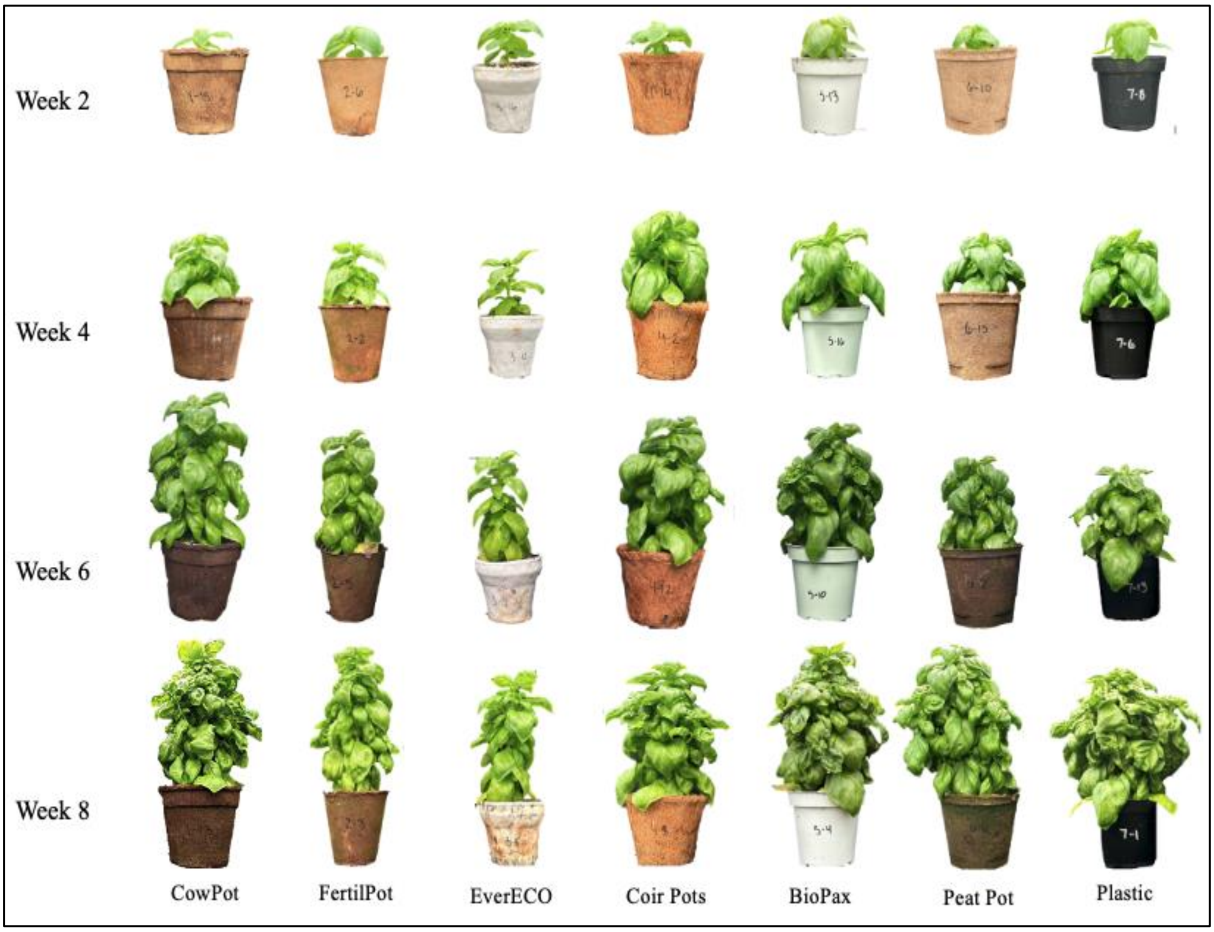

Figure 2. Progression of plant size and container state at each harvest week.

Containers of manure and coir fiber were fragile and the most difficult to dry and clean without compromising their integrity. EverECO containers were remarkably pliable and slimy when wet but dried out quickly and became brittle. BioPax containers, feeling and appearing the most plastic-like, degraded nearly three times more than plastic containers. Surprisingly, by Week 8, plastic containers had lost ~5% of their initial weight. Due to the persistence and invasiveness of microplastics in our environment, further investigations may be warranted to understand plastic fate in production systems.

Materials Testing. Material tensile strength, determined by the maximum force withstood before sample failure, was affected by container type, harvest week (Week 0, Week 4, and Week 8), condition (wet or dry), and their interactions (p=<0.0001). Since differences between container materials were distinct, mean comparisons were determined by material across harvest week and condition (**Table 2**).

BioPax containers withstood the greatest force of any container material before failure. As BioPax degraded, tensile strength improved by 44% and 73% by Week 4 and Week 8, respectively. Wetting BioPax reduced its tensile strength by 14-22% at each harvest interval. Plastic containers were able to withstand considerable tensile force without breaking.

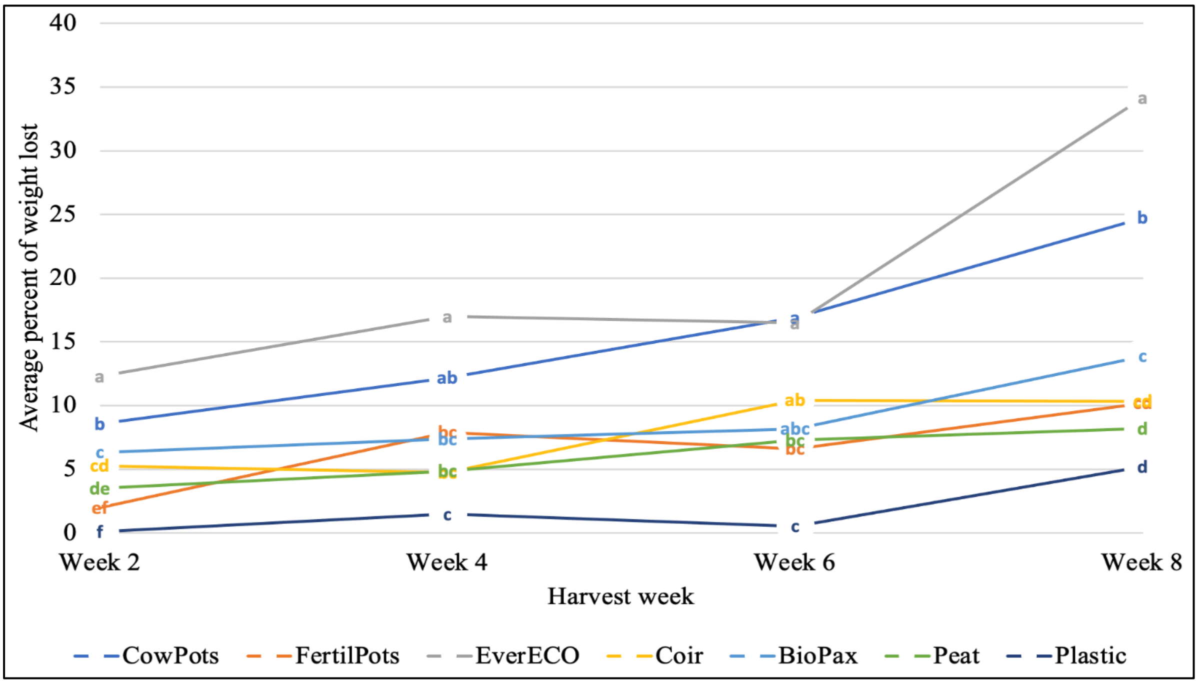

Figure 3. Average percent of weight lost from containers at each harvest date to estimate container degradation.

The elasticity of the plastic allowed the samples to stretch only, and no breakage was recorded. As expected, the tensile strength of plastic was the least impacted by hydration. While the tensile strength of BioPax and plastic increased with age, the tensile strength of other biodegradable containers exhibited decreasing trends as they aged and degraded. Hydrating biodegradable containers significantly reduced the tensile strength of CowPots, FertilPot, coir, and peat containers. Hydration of these samples often resulted in instability in handling.

Delamination occurred in containers made of coir fiber when wet. CowPots, having the lowest tensile strength, were markedly fragile when wet. Wet samples of EverECO (tapioca starch) could not be tested due to a complete loss of sample integrity. These results highlight a significant problem shared by many sustainable container types.

Consumer Opinion. Greater than half of the survey participants fell into the age group of 18-24 years old (**Table 3**). The highest percentage of participants (48%) purchased plants seasonally. Consumer purchasing habits were unaffected by age. Survey participants were most likely to buy a plant grown in a coir, BioPax, peat, or plastic container. Survey participants were least likely to purchase a plant grown in an EverECO container (**Table 4**). Few trends in consumer likeliness to purchase were observed by week. However, initial preference for FertilPot decreased sharply from Week 2, 3.54, to Week 8, 2.73.

In discussion with survey participants (post submission), many responded in favor of coconut coir containers and in disapproval of plastic containers. Often, participants thought that BioPax containers were petroleum-based and were delighted to learn the product was biobased.

Table 2. Tensile strength, determined by the maximum force (N) withstood before failure, of biodegradable, biobased, and plastic containers after 0, 4, and 8 weeks of production

		Harvest interval		
Container	Condition	Week 0	Week 4	Week 8
CowPot	Dry	9.0a[z]	8.2a	8.4a
	Wet	3.6b	2.5b	2.3b
FertilPot	Dry	40.3a	17.6b	22.9b
	Wet	5.5d	4.2d	8.7c
EverECO	Dry	79.4a	49.3b	23.0c
	Wet	--	--	--
Coir	Dry	23.2a	21.6a	12.2b
	Wet	21.2a	14.0b	8.0c
BioPax	Dry	398.5d	542.7b	622.9a
	Wet	309.1e	446.6c	534.6b
Peat	Dry	57.0a	45.5b	36.5c
	Wet	19.0d	10.8e	10.1e
Plastic	Dry	245.6b	260.2ab	277.8a
	Wet	213.8c	258.8ab	251.9b

[z] Data were analyzed using an ANOVA and subsequent means were compared within container type using the Tukey honest significant difference ($p \leq 0.05$). Means within a container type with the same letter do not significantly differ from each other.

Table 3. Demographics and purchasing habits of survey participants.

Age	% of respondents	Plant purchasing frequency	% of respondents
18-24 years old	68.8%	Once per week	7.8%
25-34 years old	12.5%	Monthly	18.8%
35-44 years old	0%	Seasonally	48.4%
45-54 years old	7.8%	Once per year	14.1%
55 or older	10.9%	Less than once per year	10.9%

Table 4. The likeliness to purchase each container changed over time.

	Container						
Harvest interval	CowPot	FertilPot	EverECO	Coir	BioPax	Peat	Plastic
Week 2	3.5[z]	3.5	2.7	3.9	3.8	3.7	3.7
Week 4	3.2	3.1	1.9	3.5	4.0	3.5	4.2
Week 6	2.9	3.3	2.2	3.8	3.9	3.8	3.5
Week 8	3.5	2.7	2.7	4.4	3.8	3.7	3.9

[z] Participants were asked to rank their likeliness to purchase a plant grown in each container type using a 1-5 scale, where "1" was very unlikely and "5" was very likely.

CONCLUSIONS

The adoption of biodegradable containers by growers in the horticulture industry is a topic with many points of concern, including the quality of plants able to be grown in them, if the containers can withstand the rigors of a typical production setting, and whether they would be marketable by the end of lengthy production cycles. This study has shown that the biodegradable containers included in this study produce plants of marketable size and quality, with the exception of EverECO tapioca starch containers. BioPax containers maintained the greatest tensile strength throughout the trial and are most likely to withstand stresses incurred in commercial production systems. With respect to marketability, EverECO and FertilPot containers were ranked lowest by survey participants after the eight-week trial. However, other sustainable container products invoked similar or greater consumer enthusiasm as traditional plastic containers. Given the consumer enthusiasm for sustainable cultivation - considerable research and product development is needed to improve the industry's trust in biodegradable and biobased containers.

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