1-1-2015

Function and Biodegradation in Soil of Bioplastic Horticultural Containers made of PLA-BioResTM Composites

James Schrader
Iowa State University, jschrade@iastate.edu

Kenneth McCabe
Iowa State University, kgmccabe@iastate.edu

William Graves
Iowa State University, graves@iastate.edu

David Grewell
Iowa State University, dgrewell@iastate.edu

Function and Biodegradation in Soil of Bioplastic Horticultural Containers made of PLA-BioResTM Composites

Abstract
Container-crops horticultural industries rely almost exclusively on petroleum-based plastic containers for modern production systems. Containers made of these materials fulfill all of the functions required during crop production, and perform better than containers made of clay, peat, and other natural materials, but the source of the plastic materials (fossil carbon), their lack of biodegradability, and their end-of-life disposal (97% end up in landfills) are major obstacles to sustainability. Although function and efficiency are among the most important aspects in determining the best materials for horticultural containers, there is no need for containers to persist in the environment for decades when their useful life cycle is only one month to three years depending on the plant species produced in them.

Keywords
Horticulture, Agricultural and Biosystems Engineering

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences | Horticulture | Natural Resources and Conservation | Polymer and Organic Materials

Function and Biodegradation in Soil of Bioplastic Horticultural Containers made of PLA-BioRes™ Composites

RFR-A1440

James Schrader, associate scientist
Kenneth McCabe, research associate
William Graves, professor
Department of Horticulture
David Grewell, professor
Department of Agricultural and Biosystems Engineering

Introduction

Container-crops horticultural industries rely almost exclusively on petroleum-based plastic containers for modern production systems. Containers made of these materials fulfill all of the functions required during crop production, and perform better than containers made of clay, peat, and other natural materials, but the source of the plastic materials (fossil carbon), their lack of biodegradability, and their end-of-life disposal (97% end up in landfills) are major obstacles to sustainability. Although function and efficiency are among the most important aspects in determining the best materials for horticultural containers, there is no need for containers to persist in the environment for decades when their useful life cycle is only one month to three years depending on the plant species produced in them.

Emerging bioplastic technologies show strong potential for use in horticulture containers that function as well as, or better than, petroleum-plastic containers during crop production, and can biodegrade in soil or compost after fulfilling their required function. Our USDA-funded Bioplastic Container Cropping Systems program has identified several bioplastic and biocomposite materials that fulfill the requirements of crop containers and can biodegrade after use. The present study examines the function and biodegradation in soil of two novel biocomposite containers made of polylactic acid (PLA) and BioRes™ (Laurel Biocomposite, Laurel, Nebraska) and compares them with two high-performing bioplastic containers and a petroleum-based container made of polypropylene (PP).

Materials and Methods

All containers evaluated in this study were injection molded. Prototype containers made of PLA-BioRes material were provided by Laurel Biocomposite, LLC. Containers made of recycled PLA were supplied by Aspen Research, Inc., Maple Grove, Minnesota and VistaTek LLC, Stillwater, Minnesota. Prototype containers made of polyhydroxy-alkanoates (PHA) and distillers dried grains with solubles (DDGS) were produced in the Center for Crop Utilization Research (CCUR) pilot plant at Iowa State University. Containers were evaluated for function and performance by growing marigold, zinnia, and pepper under standard crop-production conditions in a greenhouse for five weeks. Container materials were evaluated for biodegradability in soil by using one-fourth-sized container pieces that were weighed, placed in non-degradable mesh bags, and buried 4 in. below the soil surface on June 3, 2014. The garden plot was irrigated uniformly once per week by overhead irrigation with approximately 1 in. of water. Samples remained in the soil for six months, then were extracted, washed, dried, and weighed to determine biodegradation weight loss.

Results and Discussion

Horticultural containers made of injection-molded biobased PLA-BioRes material performed very well for the production of marigold, zinnia, and pepper (Table 1). Plants of all three species were rated equally healthy in all container types after five weeks of growth (results not shown), but plants grown in containers made of PLA-BioRes (70/30) were the largest and were significantly larger than plants grown in the petroleum-based control and recycled PLA containers, regardless of species (Table 1). Plants of marigold and zinnia grown in containers made of PLA-BioRes (80/20) were larger than plants grown in control containers, but pepper plants grown in PLA-BioRes (80/20) containers were not different in size compared with controls. The larger size of plants grown in containers made of PLA-BioRes composites demonstrates that BioRes, a modified DDGS material containing approximately 6 percent proteinaceous nitrogen, provided plant-available nutrients during the five-week greenhouse trial.

As discovered in our earlier research with biobased plastics, containers that receive high scores for durability, generally degrade very slowly in soil after use. With the exception of PHA-DDGS, which was previously shown to be durable yet highly biodegradable, containers in the present trial followed this generalization. Both the petroleum-based control and the recycled PLA containers received the highest score possible for durability, but showed little to no biodegradation during six months in soil (Table 1, Figure 1).

Containers made of PLA-BioRes (70/30) and PLA-BioRes (80/20) showed acceptable and good durability, respectively, during the five week greenhouse trial and showed good and acceptable biodegradation, respectively.

The rate of biodegradation of PLA-BioRes composites increased with increasing BioRes content (Table 1, Figure 1). Although the rate of biodegradation of PLA-BioRes was less than PHA-DDGS, our results demonstrate the strong potential for using BioRes filler to improve the biodegradability of bioplastic composites. Our results provide proof-of-concept that horticultural containers made of bioplastic composites with BioRes™ are suitable for short- to medium-cycle greenhouse crops. They also provide some intrinsic nutrients to plants during crop production and can biodegrade in soil after use.

Acknowledgements

This research was supported in part by the USDA Specialty Crops Research Initiative (NIFA-SCRI 2011-51181-30735). We thank Laurel Biocomposite, LLC, Aspen Research, Inc., and VistaTek, LLC for providing materials, processing, and collaborative expertise for this project.

Table 1. Function, durability, and biodegradation in soil of containers made of four bioplastic material types and one petroleum-plastic control.

Container material	Plant shoot volume (dm^3)[x] Marigold	Zinnia	Pepper	Container durability (0-10)[x]	Biodegradation in soil (%)[y]
PLA - BioRes (70/30)	14.4 a[z]	15.3 a	38.7 a	7.7 c	28.7 b
PLA - BioRes (80/20)	13.7 a	14.9 ab	33.7 ab	9.5 b	13.3 c
Recycled PLA	11.2 b	13.2 bc	25.2 c	10.0 a	0.1 d
Petroleum control (PP)	11.4 b	11.1 c	32.2 b	10.0 a	0.0 d
PHA - DDGS (80/20)	na	na	Na	na	38.3 a

[x]Plant shoot volume (height × width × width) and container durability ratings (appearance and structural integrity, 0 = worst and 10 = best) were measured after five weeks in standard greenhouse-production conditions.
[y]Percentage degradation of materials was calculated as the percentage weight loss of material samples during six months (one growing season) in soil.
[z]Means within a column followed by the same letter are not different according to Tukey-Kramer honest significant difference (HSD) ($P \leq 0.05$). n = 12 for plant shoot volume, n = 36 for container durability, and n = 5 for biodegradation in soil.

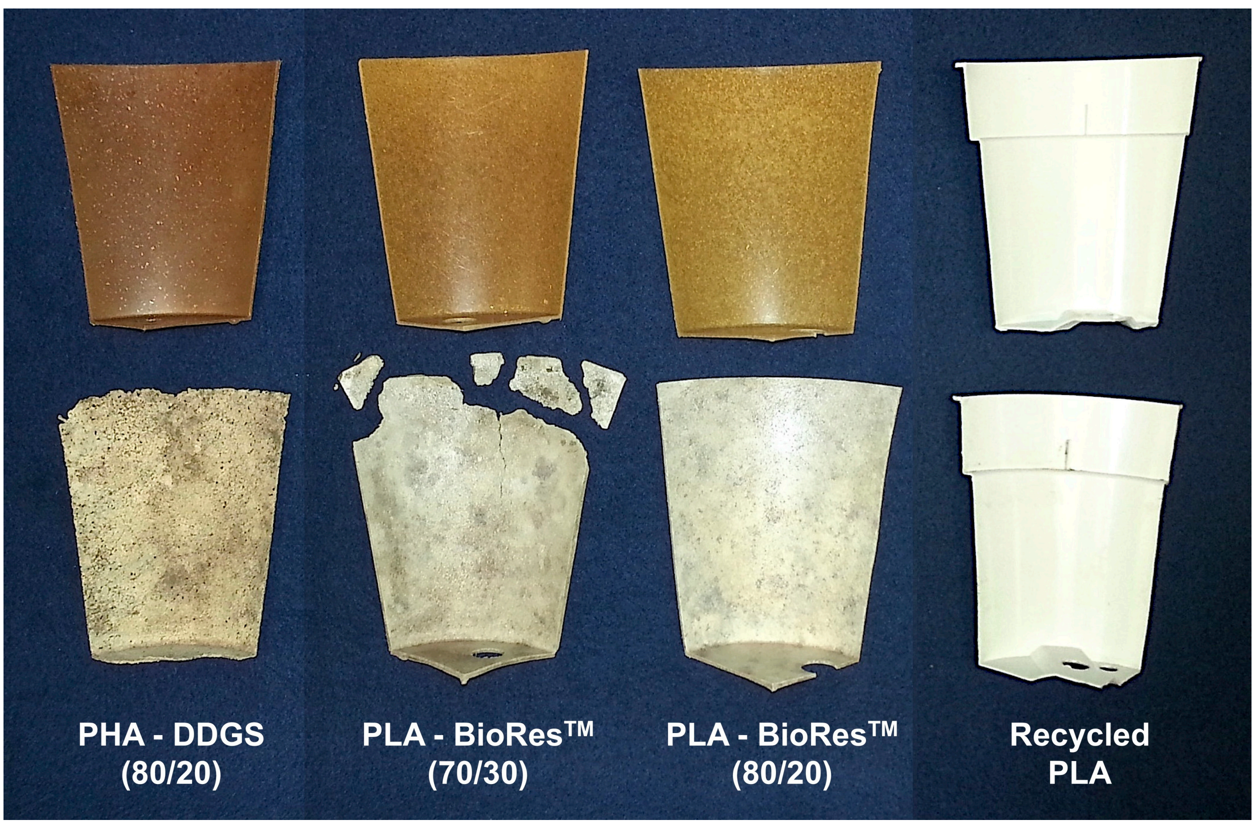

Figure 1. Samples of one-fourth container pieces as they appeared before (top row) and after (bottom row) six months in garden soil. All four container types were made of very high percentage biorenewable material (99% or more biobased carbon content).