Growth of Cyclamen in Biocontainers on an Ebb-and-Flood Subirrigation System

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SUMMARY. The objective for this research was to evaluate the growth of a long-term crop in biodegradable containers compared with traditional plastic containers using a subirrigation system. Plastic, bioplastic, solid ricehull, slotted ricehull, paper, peat, dairy manure, wood fiber, rice straw, and coconut fiber containers were used to evaluate plant growth of 'Rainier Purple' cyclamen (*Cyclamen persicum*) in ebb-and-flood subirrigation benches. The days to flower ranged from 70 to 79 and there were no significant differences between the plastic containers and the biocontainers. The dry shoot weights ranged from 23.9 to 37.4 g. Plants grown in plastic containers had dry shoot weights of 27.6 g. The dry shoot weight of plants grown in containers composed of wood fiber was 23.9 g and was lower than plants grown in plastic containers. The plants grown in the bioplastic, solid ricehull, slotted ricehull, paper, peat, dairy manure, rice straw, and coconut fiber containers had significantly higher dry shoot weights than plants grown in plastic containers. Dry root weights ranged from 3.0 to 4.0 g. The plants grown in the plastic containers had dry root weights of 3.0 g. Plants grown in paper and wood fiber containers had higher dry root weights than those grown in plastic containers. The only container that negatively affected plant growth was the wood fiber container. Plants preformed the best in solid ricehull, slotted ricehull, and coconut fiber containers based on dry shoot and dry root weights, but all containers were successfully used to produce marketable cyclamen plants.

The greenhouse floriculture crop production industry includes such commodities as flowering potted crops, perennials, and annual bedding plants. This sector of the horticultural production industry was valued at \$3.94 billion for the top 15 producing states in 2011 (U.S. Department of Agriculture, 2012). Most greenhouse floriculture crops are grown in containers. The container size is dictated by the length of time the crop will be in production and the desired finished plant size. For example, florist potted crops such as cyclamen, poinsettia (*Euphorbia pulcherrima*), and chrysanthemum (*Chrysanthemum × morifolium*) require longer production times to grow to marketability and are typically grown in larger containers than most annual bedding plants.

Petroleum-based plastics (plastic) are the most common materials

used to fabricate containers for greenhouse crop production. Plastic is relatively strong, resists mildew and algae growth, and can be molded into a variety of shapes and sizes. However, after use, these containers are typically discarded, and this results in large amounts of waste plastic containers going to landfills. One potential solution to the large amounts of waste plastic greenhouse containers is the use of biocontainers. Biocontainers are generally defined as containers that are not petroleum based and break down quickly when planted into the soil or placed into a compost pile.

Biocontainers are generally categorized as being plantable or compostable (Evans and Hensley, 2004; Evans et al., 2010). Plantable biocontainers are containers that allow plant roots to grow through their walls and

may be directly planted into the final container, the field, or the planting bed. Compostable biocontainers cannot be planted into the soil because the roots cannot physically break through the container walls and the biocontainers do not break down quickly enough to allow the plant roots to grow through the container walls. Instead, these containers must be removed before planting but can be placed in a compost pile to decompose in a relatively short time (Mooney, 2009).

There are many types of plantable biocontainers. Composted dairy manure containers are made of compressed composted cow manure held together with a binding agent. Peat containers are made from peat and paper fiber. Paper containers are made from paper pulp with a binder. Rice straw containers are composed of 80% rice straw, 20% coconut fiber, and a proprietary natural adhesive as a binder. Wood fiber containers are composed of 80% cedar fibers, 20% peat, and lime. Coconut fiber containers are made from the medium and long fibers extracted from coconut husks and a binding agent. One type of compostable biocontainer available for greenhouse production is the ricehull container, which is made of ground rice hulls with a binding agent. These containers are available in different sizes and may have solid or slotted walls. Another group of compostable biocontainers are bioplastic containers that are made from a bioplastic derived from polylactic acid or wheat starch, which is then thermoformed into containers.

Differences in growth have been reported for several bedding plant species when grown in biocontainers and compared with growth in plastic containers. Kuehny et al. (2009) evaluated the growth of pansy (*Viola × witrockiana*) and petunia (*Petunia × hybrida*) in various biocontainers. They found that the leaf area of pansy

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
1	ppm	mg·L ⁻¹	1
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

was highest when grown in wood fiber and coconut fiber containers. For petunia, the highest dry shoot weight and leaf area were found when plants were grown in peat containers. Kuehny et al. (2011) reported results of a biocontainer study on plant growth of impatiens (*Impatiens walleriana*), vinca (*Catharanthus roseus*), and geranium (*Pelargonium ×hortorum*) conducted at three locations. Impatiens shoot growth was similar for all containers, but vinca had higher dry root weight when grown in paper containers than when grown in plastic containers. The paper containers produced the highest geranium dry shoot weights at two locations and at the third location, geranium grown in plastic containers had the highest dry shoot weights. Evans and Hensley (2004) tested feather fiber, peat, and plastic containers under uniform and nonuniform overhead irrigation conditions. Under uniform irrigation conditions, the plants grown in plastic containers had significantly higher dry shoot weights than those grown in feather fiber or peat containers. The plants grown in peat containers had the lowest dry shoot weights. Under non-uniform irrigation, the impatiens and vinca had the highest dry shoot weights in the feather fiber containers, and the plants grown in plastic and peat containers had similar dry shoot weights.

Most of the research conducted on plant growth in biocontainers has been focused on short-term crops, such as annual bedding plants grown using overhead irrigation systems. However, many greenhouse crops are grown as florist potted crops that require longer production times and are often grown on subirrigation systems such as ebb-and-flood benches or flood floors. Therefore, the objective for this research was to evaluate the growth of a long-term greenhouse containerized crop in biodegradable containers compared with a traditional plastic container using a subirrigation system.

Materials and methods

The containers evaluated included 6-inch injection-molded polypropylene plastic (Dillen Products, Middlefield, OH), 6-inch solid ricehull (Summit Plastics, Tallmadge, OH), 6-inch slotted ricehull (Summit Plastics), 5-inch bioplastic (Summit Plastics), 6-inch coconut fiber (ITML

Horticultural Products, Brantford, ON, Canada), 6-inch rice straw (Ivy Acres, Baiting Hollow, NY), 5-inch peat (Jiffy Products, Kristiansand, Norway), 5.5-inch wood fiber container (Fertil International, Boulogne Billancourt, France), 6-inch paper (Western Pulp Products, Corvallis, OR), and 6-inch composted dairy manure containers (CowPots Co., Brodheadsville, PA). The dimensions of the containers tested are shown in Table 1. The 6-inch plastic container served as the control for all biocontainers.

Eight-leaf plugs (number 50 plug trays with volume of 30.8 mL; Wagner Greenhouses, Minneapolis, MN) of 'Rainier Purple' cyclamen were transplanted into the containers described above filled to the container rim with a 75 peat:25 perlite root substrate (Sun Gro Horticulture, Bellevue, WA). Cyclamen was chosen for this study because it was a long-term greenhouse crop and a day-neutral plant. All containers were placed in a glass-glazed greenhouse in Fayetteville, AR, on 1 m × 1 m × 15-cm ebb-and-flood benches. Greenhouse air temperatures ranged from 18 to 32 °C (lowest at night and highest during day). Light levels ranged from 350 to 440 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ at 1200 HR during the experimental periods. The experiment was conducted from Feb. to June 2010, Sept. 2010 to Jan. 2011, and Feb. to June 2011.

All containers were irrigated by flooding benches to a depth of 2 cm for 10 min with a solution containing 100 $\text{mg}\cdot\text{L}^{-1}$ nitrogen using a 15N-4.3P-20.8K water-soluble fertilizer (Peters Professional 15-10-25 Poinsettia Peat-Lite; Everris International, Geldermalsen, The Netherlands). Each

bench contained nine containers of a single type. Benches were irrigated individually when the moisture level of three of the containers within a bench decreased to 40% (v/v) using a moisture sensor on the soilless setting at 21 °C (Waterscout SM100; Spectrum Technologies, Plainfield, IL). The moisture level of each container was checked four times per day. The number of days from planting until flowering (anthesis) was recorded for each container. After 15 weeks, the experiment was ended and dry shoot and dry root weights were determined.

The experimental design was a complete randomized block design with an ebb-and-flood bench serving as an experimental unit and 10 ebb-and-flood benches serving as a block with three blocks over time. There were nine subsamples per experimental unit. Because of the large variability in the sizes of the containers for this study, biocontainers were only compared with the plastic control and not to one another. An analysis of variance and Dunnett means test were conducted to determine if significant differences occurred between the plastic control and the individual biocontainers.

Results and discussion

The time to flower for cyclamen ranged from 70 d for plants grown in dairy manure to 79 d for plants grown in solid ricehull containers (data not shown), with that for plants grown in plastic container being 76 d. There were no significant differences in days to flower between the plants grown in any of the biocontainers and the plastic container. The dry shoot

Table 1. Classification, height, diameter, and volume of plastic and biocontainers used in this study.

Container	Classification	Ht (cm) ^a	Top diameter (cm)	Bottom diameter (cm)	Vol (mL) ^a
Plastic	—	14.5	15.2	10.3	1840
Bioplastic	Compostable	9.5	12.5	9.5	840
Solid ricehull	Compostable	11.0	15.2	11.0	1240
Slotted ricehull	Compostable	11.0	15.2	11.0	1240
Paper	Plantable	17.0	15.8	12.0	2350
Peat	Plantable	9.5	12.7	9.0	630
Dairy manure	Plantable	12.0	15.2	10.7	750
Wood fiber	Plantable	14.0	14.0	11.0	1700
Rice straw	Plantable	17.0	14.5	10.0	1500
Coconut fiber	Plantable	9.5	15.0	10.8	1270

^a1 inch = 2.54 cm, 1 mL = 0.0338 fl oz.

weights ranged from 23.9 g for plants grown in the wood fiber containers to 37.4 g for plants grown in the coconut fiber containers (Fig. 1). Cyclamen plants grown in the wood fiber biocontainers had a lower dry shoot weight than those grown in the plastic container. Dry shoot weights of cyclamen plants grown in all other types of biocontainers were higher than those of plants grown in the plastic container.

The dry root weights ranged from 3.0 g for plants grown in plastic and bioplastic containers to 4.0 g for plants grown in the paper containers (Fig. 2). Cyclamen plants grown in the paper and wood fiber containers had higher dry root weights than those plants grown in the plastic

container, but plants grown in the bioplastic, solid ricehull, slotted ricehull, peat, dairy manure, rice straw, and coconut fiber containers had similar dry root weights as those grown in the plastic container.

Currently, no studies have been published on days to flower for plants grown in biocontainers as compared with plastic containers. In previous research (Evans and Hensley, 2004; Kuehny et al., 2011) on plant growth in biocontainers, authors have determined plant growth, as measured by dry shoot and dry root weight, at a specified point in time but did not record days to flower. Days to flower are typically directly related to days to marketability for many floriculture crops species, so increasing days to

flower would increase the time required to produce a marketable crop. This is important because an increased time required to grow plants to marketability would increase inputs and the cost of production. Because container type had no effect on days to flower for cyclamen in an ebb-and-flood subirrigation system, the production time would not change if a greenhouse company switched from plastic containers to any of the biocontainers evaluated in this study.

The wood fiber container produced a smaller plant than the plastic container as measured by dry shoot weight. This was contrary to a study conducted by Kuehny et al. (2011), which reported that wood fiber containers produced geraniums and impatiens of similar size to those grown in plastic containers. This may have been due to the differences in plant species used in the studies or the irrigation method used. In our study, an ebb-and-flood subirrigation system was used, whereas Kuehny et al. (2011) used overhead hand watering. The wood fiber containers did not have holes in the bottom. On flooding of the benches, the fertilizer solution had to be first absorbed by the container wall before the solution could move into the substrate. In fact, this resulted in less fertilizer solution being absorbed per irrigation for wood fiber containers as compared with plastic containers (Beeks, 2011). In addition, the wood fiber containers also had the shortest irrigation interval and dried out faster than the other containers. As a result of less fertilizer solution being taken up into the substrate, cyclamen plants in wood fiber containers may have experienced mild water stress as compared with plants grown in plastic containers. Kuehny et al. (2011) used overhead irrigation, so the fertilizer solution was applied directly to the substrate and the issue of the solution moving through the wood fiber container wall would not have occurred. Therefore, substituting plastic containers with wood fiber containers in a subirrigation system resulted in smaller cyclamen plants that required more frequent irrigations which would have increased the cost of production. All other containers had cyclamen with higher shoot dry weights than plastic.

Kuehny et al. (2011) demonstrated that there was a significant

Fig. 1. Dry shoot weights of 'Rainier Purple' cyclamen grown in 6-inch (15.2 cm) plastic containers and various biocontainers after 15 weeks in an ebb-and-flood system. Bars noted with a * were significantly different from the plastic control as determined by the Dunnett mean test ($\alpha = 0.05$); 1 g = 0.0353 oz.

Fig. 2. Dry root weights of 'Rainier Purple' cyclamen grown in 6-inch (15.2 cm) plastic containers and various biocontainers after 15 weeks in an ebb-and-flood system. Bars noted with NS or * are not significantly different from the plastic control as determined by Dunnett the mean test ($\alpha = 0.05$); 1 g = 0.0353 oz.

interaction between plant species and biocontainer type with respect to dry root weights. Dry root weights of *impatiens* grown in biocontainers were similar to those of plants grown in plastic containers, and dry root weights of geranium grown in wood fiber containers were lower than those for plants grown in plastic containers (Kuehny et al., 2011). With cyclamen, we found that all plants grown in biocontainers had dry root weights that were equal to or higher than those grown in the plastic containers. Therefore, for cyclamen, there were no deleterious effects on root growth when plants were grown in biocontainers on ebb-and-flood benches.

Conclusion

There was no difference in production times between cyclamen grown in biocontainers and those grown in plastic containers on an ebb-and-flood production system. Cyclamen grown in biocontainers

had higher dry shoot weights and similar or higher dry root weights as those grown in the plastic containers except for those grown in wood fiber containers, which had a lower dry shoot weight than the plastic control. In the case of wood fiber containers, the reduction in dry shoot weight was not high enough to make the plants unmarketable. Therefore, greenhouse crop growers could switch from growing long-term crops such as cyclamen on ebb-and-flood subirrigation systems in 6-inch plastic containers to an equivalent biocontainer and successfully grow similar size and quality cyclamen plants within the same production time.

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