Root and Shoot Responses of 'Miss Kim' Lilac to Container Type and Environment[1]

Catherine A. Neal[2]
Department of Biological Sciences, 38 College Road
University of New Hampshire, Durham NH 03824

Abstract

Growth and quality of 'Miss Kim' lilac produced in two container types (plastic and fabric) and in above ground (AG) versus below ground (BG) systems were compared. Plants were overwintered in place for 2 or 3 years with no additional protection, except in a combined AGBG treatment where pots were AG during the growing season then placed in BG socket pots for winter. Survival and shoot biomass were equal in both container types within the AG or BG systems. The AG systems reduced top and root dry weights compared to BG systems; however, survival and plant quality were not adversely affected except in a bag in pot (BIP) system. Root distribution and morphology, but not mass, were affected by container type, with more small-diameter roots distributed uniformly throughout the substrate in fabric AG containers. Containers inserted into BG sockets (as in pot in pot growing systems) were insulated from lethal high and low root zone temperatures (RZT). These treatments produced the greatest amount of root and shoot growth and are suitable for container production systems in northern areas. Plants reached the same size whether in plastic or fabric liner pots within the BG system. The BG environment, however, did not alleviate root circling and matting. Growth was reduced in AGBG containers as well as AG containers, indicating that winter root mortality was not the only limiting factor. Roots in AGBG experienced the same winter RZT as BG treatments, yet the top and root dry weights were reduced by 41 and 60 percent respectively, in comparison to BG. Environmental stress in AG containers during the growing season may limit growth more than commonly realized.

Index words: nursery production, pot in pot, root temperature, cold stress, heat stress.

Species used in this study: lilac (*Syringa pubescens* subsp. *patula* 'Miss Kim').

Significance to the Nursery Industry

This research investigated the possibility of leaving AG containers in place year-round, eliminating the expense and labor associated with traditional methods of winter protection. Although this may seem counter-productive to most northern nursery growers, the resulting reduction in growth may not be economically significant for many species. All plants were of saleable quality at the end of the study, with the exception of the BIP treatment. In other work (10) fabric containers enhanced cold tolerance and increased survival of plants such as *Physocarpus opulifolius*, *Viburnum trilobum* and *Weigela florida* compared to those grown in plastic containers when left unprotected over the winter; however, in this study, there was no difference in lilac growth attributed to container type.

Plants in fabric AG pots had more fibrous and small diameter roots distributed throughout the substrate volume, and

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[2]Extension Professor. cathy.neal@unh.edu.

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had less root circling than plants in AG or BG plastic pots, presumably due to air root pruning resulting from drying at the porous container wall. Placing fabric pots in plastic liner pots BG, however, reduced the beneficial effects of fabric containers on root morphology, resulting in more surface root density and more large-diameter circling roots.

Introduction

Production of woody plants in AG plastic containers provides a very different root environment than field production. Exposure to extreme high and low temperatures in container production results in root mortality and may result in low survival rates, longer production cycles and/or reduced plant quality (7). In addition, the container restricts the natural radial growth pattern of roots, resulting in bent, circling, matted or otherwise modified root structure that may impact the long-term viability of woody landscape plants (1).

Overwintering container stock in the northern latitudes of the United States typically involves labor-intensive efforts to move, stack and/or cover plant inventory in late fall and then reverse the process in spring. The objective is to protect the roots from lethal low temperatures since roots, having evolved in a well-buffered soil environment, are not as cold tolerant as shoots. Mature roots of deciduous temperate zone woody plants are killed when temperatures fall below a threshold temperature, generally between –5 and –23C (23 to –9.4F), depending on the species (3). The lethal threshold may be several degrees higher for young roots of the same plant (16). At the other extreme, root growth and function diminishes rapidly and cell death occurs between 30 and 35C (86 to 95F) (5, 13).

Pot-in-pot (PIP) systems were developed in the southern U.S. to insulate roots from lethal high temperatures and to alleviate wind throw of large container stock (14). However, PIP systems are expensive to install (2) and reduce the grower's flexibility to change product and pot size since the liner pots must match the semi-permanent socket pots in size and shape. Nurseries may also be challenged by soil or drainage conditions that make PIP systems problematic. Neal (9) determined that PIP provided adequate winter protection in zone 5 for many temperate deciduous plants, since minimum substrate temperatures were only a few degrees lower than the surrounding soil. However, it was observed that the substrate warmed more slowly in PIP than in AG containers in the spring, delaying root growth, which is highly temperature dependent. It was also observed that many shrub species overwintered in fabric AG containers had excellent survival rates compared to the same shrubs in plastic AG containers (10).

An epidemic of landscape failures has largely been blamed on production and planting practices associated with defective or girdling roots (19). With container production increasing in scope (4), a better understanding of the effects of various container types on root morphology is needed. Many attempts have been made to modify containers to create better root systems, most involving air-root pruning or a chemical inhibitor such as copper hydroxide. Woven or nonwoven geotextile fabric containers have been used successfully to modify root structure and reduce defects, although results vary with species and climate.

Tauer and Cole (17) reported no differences in average daily high and low substrate temperatures due to fabric vs. plastic container type when sensors were placed in the centers of #10 containers. However, other studies in diverse geographical areas of the U.S. document that RZT in plastic containers regularly exceeded lethal thresholds in the southwest quadrant of the container, resulting in root mortality in the outer cylinder of substrate (6, 8, 10, 15). Porous fabric containers greatly reduce the daily temperature fluctuations experienced by the outer cylinder of roots and the porous fabric allows for evaporative cooling through the sides. No reports of root death from high temperatures in fabric containers were found in the literature.

There has been a limited amount of container production research conducted in the northern U.S. and studies rarely address the cumulative effects of environmental factors over more than one growing season. The current study was designed to investigate the potential for reducing overwintering requirements in northern container nurseries by comparing plants overwintered in AG containers with those in BG PIP production systems, and plastic versus fabric containers (plus a combined BIP treatment consisting of a fabric-liner pot in an AG plastic socket pot). It was also designed to evaluate whether root and shoot growth in northern nurseries could be optimized by seasonally shifting containers from above-ground to below-ground systems according to the time of year, substituting for more labor-intensive overwintering techniques.

Materials and Methods

Syringa pubescens subsp. *patula* 'Miss Kim', commonly produced in containers in the Northeast and widely used in landscapes, was selected as the test species. A factorial 2 × 3 set of treatments (listed in Table 1) was designed to compare container type and environment. A seventh treatment (BIP) consisted of a black fabric liner pot within an AG plastic outer pot.

Liners were transplanted from 32-cell trays to #7 plastic (Nursery Supplies Inc., Chambersburg, PA) and fabric containers (High Caliper Growing Systems, Oklahoma City, OK) on June 13, 2005, filling each container with an equal volume of substrate. Plants were arranged in double rows with 1.8 m (6 ft) between rows and 1.2 m (4 ft) between pots within rows in a nursery block with underlying well-drained sandy loam soil. There were nine plants per treatment in a completely randomized block design (one plant per treatment per block) with border plants at each end of each row.

The substrate was a commercial bagged mix (pine bark:peat:sand, 8:2:1 by vol; Conrad Fafard Inc., Agawam, MA). All plants were fertilized soon after planting with Nutricote Total (Chisso-Asahi Fertiizer Co., Tokyo, Japan) [18N-2.6P-10K, Type 100, 84 g (3 oz) per plant]. Subsequent applications of Nutricote Total fertilizer were made in May 2006 [Type 140, 117 g (4.1 oz) per plant], 2007 [Type 70, 50 g (1.8 oz) per plant] and 2008 [Type 40, 20 g (0.7 oz) per plant].

Microsprayers [26.5 liters (7 gal) per hour, Netafim Irrigation, Inc., Altamonte Springs, FL] were installed and used as needed May through September of each year. Water was applied when the top 5–6 cm (2–3 in) of substrate was dry to the touch and no appreciable rain was predicted. In hot dry periods, the irrigation ran once daily (6 liters (1.7 gal) per pot). Hose watering was performed during October and April to maintain moisture in the substrate when precipitation was inadequate.

Table 1. Means and one-way ANOVA for treatment effects on shoot growth and flowering of 'Miss Kim' lilac.

Treatment					
Container type	Environment[z]	Inc. in ht[y] (cm) (final ht – initial ht)	No. stems at termination	Top dry wt (g)	Inflorescence no. June 2006
Fabric	BG	44.8a	8.5a	337.2a	17.1a
Plastic	BG	44.0a	8.5a	300.9a	13.4a
Plastic	AGBG	30.7ab	7.4ab	216.7b	12.9a
Fabric	AGBG	30.4ab	7.0ab	223.2b	11.6a
Fabric	AG	31.7ab	6.3ab	193.7b	14.6a
Plastic	AG	33.6ab	6.4ab	196.4b	14.4a
Bag in pot	AG	22.2b	4.2b	113.1c	3.4b
ANOVA	Df	*Pr* > F	*Pr* > F	*Pr* > F	*Pr* > F
HG[x]	1	.0717*	.1607	<.0001***	.1569
Block [HG]	6	<.0001***	.0038***	.0003***	.0030***
Treatment	6	.0002***	.0107**	<.0001***	<.0001***
Error df		38	36	39	40

[z]AG = above ground (exposed to ambient conditions all year, no winter protection), BG = below ground (inserted in plastic socket pot, equivalent to pot-in-pot system), AGBG = alternating above ground (warm season) and below ground (cold season) environment.

[y]Means within columns not followed by the same letter are significantly different at $P \leq .05$ by Tukey's pairwise comparison. *, **, *** denote significance at Pr > F = .10(*), .05(**) or .01(***).

[x]HG (harvest group): HGA was pulled from the field in November 2007 and final measurements taken in February 2008 after winter storage in a cooler. HGB was left in the field until July 2008 and final measurements were taken at that time.

Weed control the first two seasons was achieved by hand pulling small weeds within pots and hoeing as needed between pots. A glyphosate spray application was made between pots on May 25, 2007. OH-2 herbicide (oxyfluorfen + pendimethalin, The Scotts Co., Marysville, OH) was applied to the substrate surface in each pot on May 15, 2008. Lilac borer damage had been noted in prior years at this location, so preventative stem applications of Talstar (bifenthrin, FMC Professional Solutions, Philadelphia, PA) were applied in June 2006 and June 2007, timed by trapping adult moths with pheromone traps.

The trial was conducted during a period of above-normal temperatures and precipitation (18). Nearly 60 cm (23.6 in) of rain in May–June 2006 saturated the soil and flooded the below-ground socket pots. Liner pots were pulled from the BG treatments and set on the soil surface between May 15 and 24, 2006, and again June 8–11. AGBG treatments were inserted into socket pots during the following periods: October 21, 2005–April 19, 2006, November 30, 2006–May 12, 2007, November 30, 2007–May 7, 2008.

Temperature sensors and data recorders (Hobo H8 Outdoor/Industrial loggers, Onset Computer, Pocasset, MA) were installed in representative pots of each treatment, programmed to log RZT every 30 minutes from July 5, 2005, through May 13, 2008. Sensors were placed in the southwest quadrants of containers, 10 cm (4 in) deep and 2.5 cm (1 in) inside the pot wall.

Plant size (ht and spread) was measured at the beginning of the trial and at the end of each growing season. The numbers of stems over 0.6 cm (0.25 in) diameter that originated in the lower ¼ of the plant were counted on November 30, 2006, and at termination. Observations on branch dieback, stem cracks, plant vigor and leaf color were made periodically. Inflorescence counts were made at full bloom on June 5, 2006, and June 25, 2008; inflorescences were then clipped, dried and weighed in 2008.

Five blocks of plants designated as harvest group A (HGA) were moved from the field to a walk-in cooler on November 27, 2007, and maintained at 3.3–4.4C (38–40F). On February 29, 2008, the tops were cut at soil level, dried in a greenhouse at ambient temperatures and then weighed on April 7. Rootballs from four of the five blocks of plants were removed from the cooler and processed (washed, cut, cleaned and dried) in random order over an eight week period (March–April 2008).

Three blocks of plants (harvest group B, HGB) remained in the field for the third winter. These plants were consolidated on or about December 1, 2007, to maintain the desired pot spacing. It was observed that plants in fabric pots were well-rooted into the underlying soil at that time. On July 11, 2008, the tops were cut, dried for 2 weeks at 38C (100F), then weighed. Rootballs were rated for surface density on two faces of the ball (east and west exposures). Following washing with a high pressure water stream to expose the majority of roots, roots were again rated for overall density, distribution and morphology.

One-way ANOVA with means separation was performed on shoot growth response variables (increase in ht, no. stems, top dry wt, inflorescence counts and dry wt) for the entire dataset, nesting blocks within harvest groups. One block was excluded because of disturbance during the experimental period.

HGA was also analyzed independently for top dry wt, root dry wt and root to shoot ratio. Due to poor survival, the BIP treatment was excluded from this data subset and the remaining six treatments were analyzed as a complete factorial experiment. All statistical analyses were performed with JMP 8.0 (SAS Institute, Cary, NC).

Results and Discussion

Table 1 shows significant treatment differences in shoot growth and flowering for the combined dataset (HGA + HGB). Since HGB was in the field for seven months longer than HGA, top dry weight was significantly greater. Plants in BIP were the least vigorous and flowering was suppressed, confirming visual observations throughout the course of the

Table 2. **Top and root dry weight and root to shoot ratios for harvest group A, four blocks of plants pulled from field in November 2007, stored in a cooler and processed for root dry weight. Bag in pot treatment is not included due to poor survival to this point.**

ANOVA	Df	Top dry wt[z] (g) *Pr* > F	Root dry wt (g) *Pr* > F	Root:shoot *Pr* > F
Block	3	.0190**	.0438**	.1700
Container type	1	<.0650*	.9636	.1361
Environment	2	<.0001***	<.0001***	.5056
Container × Environment	2	.7566	.2176	.0518*
Error df	15			
Means ± SE for main effects				
Container type	fabric	192.2 ± 5.5	289.7 ± 12.6	1.52 ± .04
	plastic	176.8 ± 5.5	289.8 ± 12.6	1.61 ± .04
Environment	AG[y]	145.9 ± 6.7	236.8 ± 15.4	1.62 ± .05
	AGBG	155.1 ± 6.7	239.2 ± 15.4	1.54 ± .05
	BG	252.6 ± 6.7	391.8 ± 15.4	1.54 ± .05

[z]*, **, *** denote significance at Pr > F = .10(*), .05(**) or .01(***).

[y]AG = above ground, BG = below ground, and AGBG indicates alternating above ground (warm season) and below ground (cold season) treatment.

experiment. Only fifty percent of plants in BIP survived two growing seasons, compared to 87–100 percent survival in other treatments, and the majority of plants in BIP had stem cracks and branch dieback. The other AG treatments as well as the BG treatments showed negligible cracking or dieback. There were no differences in flowering among treatments (excluding BIP), as shown in Table 1 for 2006; 2008 inflorescence counts and dry weights also were not significantly different within HGB (data not shown).

Table 2 presents factorial analysis of the data from HGA. The main effect of container type was significant only for top dry weight (Pr > F = 0.06), which was higher in fabric than in plastic containers. Root dry weight was surprisingly consistent between the two container types. Top dry weight and root dry weight were both significantly affected by environment with BG plants having greatest growth of both roots and shoots; however, root to shoot ratio was not significantly affected. There was an interaction between container type and environment for root to shoot ratio, due to the fact that the ratio was the same for plastic containers regardless of environment, but was higher in AG fabric containers than in BG fabric containers.

When HGB was subjected to destructive root examination in July 2008, it was evident that both container and environment were important factors affecting lilac root distribution and morphology. Woody plant failure in the landscape is often attributed to root defects formed during nursery production, most severely in smooth-sided plastic containers. This problem may be exaggerated by PIP systems, which reduce root mortality from temperature extremes, thus roots are not 'pruned' to stimulate regeneration of smaller new roots. In this trial, lilac roots in plastic BG containers were heavily matted and had many circling, large diameter roots and many root escapes through the drainage holes. Root circling and defects were less prevalent in AG or AGBG plastic pots, presumably checked by direct temperature injury. Root density on the west-facing surface of the rootball was lower than the east side, as expected from exposure to super optimal temperatures in plastic containers; there was no corresponding injury to roots in fabric AG containers. Root systems in AG fabric containers were characterized by an abundance of small diameter roots uniformly well-distributed throughout the substrate volume, although not visible on the surface of intact rootballs. Inserting fabric pots into BG plastic sockets reduced the air root pruning benefits, resulting in greater density and more large-diameter roots in the outer cylinder.

The minimum RZT recorded during the coldest week of the trial (Fig. 1) were –18C (–1F) in plastic AG, –12C (10F) in fabric AG, –5C (22F) in plastic BG, and –3C (26F) in fabric BG, with a minimum air temperature of –19.5C (–3F). AG fabric containers cooled at a slower rate and maintained RZT 4–8C (2–4F) higher than AG plastic containers during extreme cold events. RZT differences between plastic and fabric BG containers were consistently less than 2C (1F), so data is not shown for fabric BG containers in Fig. 1.

The lethal cold temperature threshold for mature lilac roots has not been reported in the literature but presumably is less than –18C (–1F), the minimum RZT reached in this trial. Extensive young (immature) root dieback occurred in both AG container types, but plants recovered and grew normally the following season, evidence that mature roots are more important than immature roots in recovery from winter injury (11).

Root dry weight was reduced by forty percent in containers maintained year-round in AG versus BG environment, although plant survival was not reduced by these treatments.

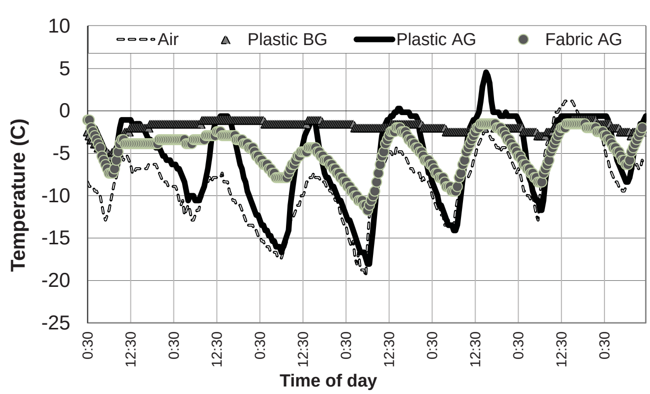

Fig. 1. **Air and substrate temperatures recorded during one of the coldest weeks in the trial period, February 16–March 3, 2006.**

What is more surprising is that AGBG plants, grown AG during the warm season then placed in BG sockets for the winter, had root and shoot dry weights equal to those plants maintained AG all year. If low RZT were the primary limitation to growth in this trial, the AGBG plants would have been equivalent to BG treatments rather than AG treatments. It is evident in Table 1 that shoot growth (top wt) in the AGBG treatment, while not significantly different from the AG treatment, was intermediate between AG and BG. This leads to the hypothesis that differences in growth were affected more by limitations in the warm season than in the winter. RZT in plastic continued to exceed optimal ranges on sunny days throughout the fall, but then cooled rapidly at night, resulting in a daily RZT fluctuation of up to 40C. These temperatures may modify normal patterns of acclimation and carbohydrate accumulation (12).

Roots in AG fabric pots are buffered from lethal summer RZT and are better distributed throughout the container as well. But in this trial, root dry mass was the same in either AG container type, despite observed differences in density and morphology. This suggests that plants compensate for temperature-induced mortality through root regeneration, which may come at the expense of storage carbohydrates that would otherwise be available for shoot growth. Higher root respiration rates in warmer environments of plastic containers could also have reduced the amount of energy available for shoot growth and metabolism, explaining the reduced top dry weights for fall-harvested plants, as shown in Table 2. Many interconnected physiological processes are altered by root temperature stress, which remains a major limiting factor in container nursery production.

Controlled experiments comparing plant responses to AG container types are rare and limited primarily to southern latitudes, and have shown mixed results, dependent on species. Growers have debated the pros and cons of fabric containers for over two decades, but most of the published reports are from in-ground systems such as grow bags (see citations in 17). The current research shows that AG fabric containers do have advantages in RZT modification and reduction in circling/defective roots but that these advantages are not necessarily reflected in increased growth or quality during the production cycle.

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