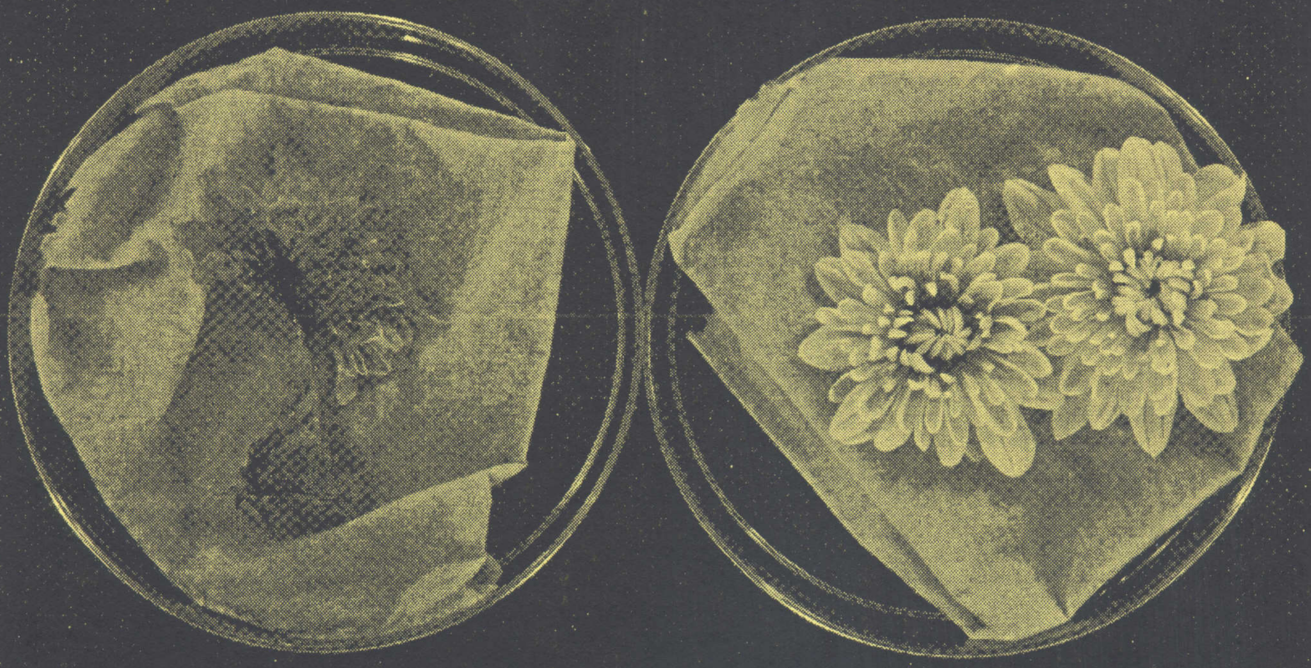
2001 Ornamentals Research Report



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CONTENTS

WOODY ORNAMENTALS

HERBACEOUS ORNAMENTALS

INSECT, DISEASE, AND WEED CONTROL

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WOODY ORNAMENTALS

Alabama Nurseries Adopt Best Management Practices

Glenn B. Fain, Charles H. Gilliam, Ken M. Tilt, John W. Olive, and Beth Wallace

In the 1960s and early 1970s public outcries brought on many revolutionary changes in environmental laws. Probably the most important of these laws was the 1972 Water Pollution Control Act (renamed the Clean Water Act in 1977). In 1977 the Clean Water Act was updated to address non-point source pollution.

The Clean Water Act of 1986 mandated EPA to address non-point source pollution problems. Non-point source pollution is controlled primarily through practical and cost effective best management practices (BMPs) adopted through proactive and voluntary support from the targeted industry. This is unlike the point source pollution of many industries, which are mandated to collect and treat wastewater prior to it leaving the production site. In a 1987 update of the Clean Water Act, authorization was given to each state to assess non-point pollution and to implement management plans. Nursery production runoff water, like that from most agricultural industries is classified as non-point pollution.

Due to concerns of potential contamination from nursery runoff water in the coastal area of south Alabama, the Alabama Department of Environmental Management (ADEM) began discussion in the late 1980s with the Alabama Nurserymen's Association (ANA) to address this potential problem. The ANA in conjunction with Auburn University developed a limited set of BMPs to address the ADEM concerns. Subsequently the Southern Nurserymen's Association (SNA) developed interest in expanding the scope of Alabama BMPs to include the 16 states in the SNA. Thereafter the SNA led a cooperative effort among container nursery producers, university personnel, EPA, and ADEM to address concerns related to potential problems with water management in container production nurseries across the southern United States. This cooperative effort resulted in development of a site-specific, menu-driven BMPs manual published by the SNA.

Development of BMPs for Alabama's nursery industry began in the late 1980s and by the late 1990s nurseries in south Alabama had already incorporated many BMPs into their operations. In order to determine which and to what extent BMPs had been incorporated at these nurseries, we conducted a survey using personal interviews with nursery owners and key management personal at several production facilities in south Alabama.

Water and Fertilizer Management Practices in South Alabama Container Nurseries (1998)

Water use management	Percent by nursery size[1] small	medium	large
Water use management			
Water early in the A.M. when possible	38	38	57
Cyclic irrigation	38	25	0
Monitor irrigation efficiency	50	57	33
Increase media water-holding capacity	75	43	57
Collection pond	63	75	100
Installation of grass filter/erosion strips	63	75	63
Runoff water captured (% captured)	50 (98)	75 (83)	100 (75)
Recycle runoff water (% recycled)	13 (100)	25 (48)	38 (68)
Ever tested runoff water	25	38	100
Test runoff water regularly	13	38	63
Specific person(s) devoted to water management	100	100	100
Fertilizer use management			
Controlled release fertilizer only	50	100	50
Controlled release fertilizer primarily	50		50
Liquid feed liners	75	25	25

[1] Nursery size: small 1-10 acres, medium 11-40 acres, and large 40+ acres.

METHODS

Twenty-four container production nurseries in south Alabama were surveyed during the spring of 1998. Nurseries were divided into three categories: small nurseries with 1-10 acres of production, medium nurseries with 11 to 40 acres, and large nurseries with more than 40 acres of production. There were eight nurseries in each category with a total of 838 acres of actual production area. Nurseries surveyed represent about 80% of the total estimated acreage in Mobile and Baldwin counties in south Alabama. This survey was conducted using an extensive questionnaire pertaining to BMPs and water quality strategies. The questionnaire was divided into four sections: water, fertilizer, pesticide management, and pesticide selection.

RESULTS

One of the most dramatic findings of this survey was that 75% of all nurseries, representing 93% of the total acreage surveyed, captured some or all of their runoff. Seventy-eight percent of all collection ponds had been built since 1988 when discussion of BMPs first began and 44% of those had been built since 1993 (see table). Collection ponds for collecting and recycling nursery runoff are one of the most important BMPs nurseries can implement.

Another BMP designed to reduce water applied as well as minimizing runoff is the direct monitoring of irrigation systems. All nurseries in our survey stated they had specific personnel devoted to water management, with about half of those nurseries involved in direct monitoring of irrigation efficiency. The amount of irrigation water plants need at any given time depends on several factors such as container size, species, container substrate, growth stage, environmental conditions, and time of year. In order to optimize the efficiency of irrigation systems, plants need to be grouped according to irrigation requirements based on these factors and then irrigated based on plant need which can vary from day to day. In past years, many nurseries may not have been concerned about water-use efficiency due to the abundant supply of clean water. However, a critical step in reducing runoff water is to apply the minimum amount of water needed for optimal plant growth.

One goal of the BMPs is to minimize the amount of effluent escaping the bottom of the pot during and after an irrigation event. While grouping plants based on water needs can help minimize effluent, other practices such as cyclic irrigation and increasing media water holding capacity may also reduce container effluent. When questioned about these practices, 38% percent of small nurseries stated they used cyclic irrigation to reduce runoff water while no large nurseries reported cyclic irrigation use. Limited use of cyclic irrigation with large nurseries is probably due to difficulty in managing irrigation schedules around their large labor forces. Seventy-five percent of smaller nurseries incorporated peat, coir, or rice hulls to increase container substrate water retention while 43% of medium and 57% of large nurseries adjusted their media to hold more water.

With respect to fertilizer BMPs, all nurseries either used control release fertilizer only or used it as the primary source of fertilizer for their container grown plants. While not specifically questioned in the survey, several growers indicated that in the past they had used liquid fertilization, but had discontinued this practice after becoming aware of the potential for environmental problems associated with this practice, when complete capture of irrigation runoff is not feasible.

To determine pest management practices, nurserymen were questioned as to how their pesticide treatment/application methods had changed over the past three years. Areas targeted for questioning were scouting for pests, using horticultural oils, using electrostatic sprayers, using bio-control agents, applying herbicides to jammed containers, and staggering herbicide applications. Several changes had occurred with the most notable being increased scouting for pests. This indicates a shift towards targeting pesticide applications for specific needs as opposed to previous use of preventative sprays. Another change closely following increased scouting was the use of horticultural oils. Seventy-five percent of small and medium nurseries used more oil during the past three years than in prior years.

Another important BMP for nurseries to consider is the installation of a central location for the storing/mixing of chemicals to increase worker safety and to minimize and or contain any spills that may occur during mixing and rinsing. Thirty-eight, 50, and 67% of the small, medium and large nurseries, respectively, had a central pesticide mixing and rinsing station. Fifty-eight percent of all central pesticide rinsing and mixing stations at surveyed nurseries have been built in the last five years. While half of all nurseries had rinsing and mixing stations, most remaining nurseries had plans to construct one in the future.

Nurseries were questioned about what species or varieties they may have eliminated from production due to unusually high pesticide inputs need to grow those crops. Eighty percent of all nurseries had eliminated one or more species from production due to that species' need for frequent pesticide applications. Species listed as eliminated were *Photinia fraseri* (70%) and *Euonymus japonicus* 'Aureus' (33%). Rhododendron was the only other genera mentioned more than once.

In concluding our survey we asked nurseries to comment about any other BMPs they might foresee being incorporated in their future operations. Responses included better education in dealing with pesticides, increased worker training, installation of wetland plants, installation of grass waterways, installation of windbreaks, and moving from production areas with urban encroachment to more rural areas to avoid negative public perceptions.

Due to the positive response of this survey, it is evident that nurseries in south Alabama have been willing participants in the BMPs concept. These nurseries are proactive in addressing those environmental issues relating to production of container-grown nursery crops that not only effect the future of their businesses but the future of our industry as a whole. While future regulations regarding water quality and availability are likely to be imposed on the nursery industry, this survey indicates that many nurseries are forward thinking and proactive in their willingness to implement management practices designed to improve environmental stewardship when a clearly defined program is presented.

Atrimmec Suppresses Shoot Length of Goldflame Honeysuckle

L.L. Bruner, G.J. Keever, J.R. Kessler, Jr., and C.H. Gilliam

Lonicera ×heckrottii or Goldflame honeysuckle is characterized by 10 to 20 foot long shoots and continuous blooming throughout spring and summer. This semi-evergreen vine fills a unique niche in the landscape due to its twining, climbing habit, and long season of prolific flowering. These characteristics, combined with its attractive carmine flowers opening to expose a yellow corolla, make it a popular plant with consumers. New Goldflame honeysuckle shoots are supple, lithe, and twine readily. The lower portions of the plant become woody and rigid as the season progresses. New growth late in the season differs from early season growth by not twining as readily.

Container production of this plant can be difficult due to its rapid growth and twining nature. Plants often grow to an undesirable size and intertwine with adjacent plants making handling and transport to market difficult. Hand pruning is a standard maintenance practice for controlling plant shoot length and increasing branching. It must be begun early and repeated frequently to develop compact, full plants. However, pruning is time-consuming, labor-intensive, and often removes flowers.

Atrimmec is both a plant growth retardant (PGR) and branching agent that may offer benefits in the production, shipping, and marketing of Goldflame honeysuckle. Atrimmec is labeled for use on numerous woody plant species, but not specifically for use on Goldflame honeysuckle.

Today's retail nursery market influences cultural practices in production, compelling growers to extend production later into the growing season to meet consumer demands during the summer. One challenge facing growers using PGRs is the different plant responses when PGRs are applied at different physiological stages of development during the growing season. Industry guidance suggests PGR efficacy decreases with increasing plant size and physiological development. Production practices often necessitate size or branching control later in the season on plants marketed in summer when plants are larger and more physiologically advanced.

Atrimmec is commonly used in landscape maintenance to reduce the frequency of pruning. Depending on desired plant appearance, the Atrimmec label suggests either pruning immediately before application or pruning and allowing at least 2 inches of growth before application. The label states uptake is best on soft, fully developed leaves, and if plants are pruned before application, at least two pairs of expanded leaves should be present at the time of application.

The objective of our research was to determine the effects of Atrimmec on non-pruned and pruned Goldflame honeysuckle at a late application and the effects of Atrimmec on non-pruned Goldflame honeysuckle at an early application during the growing season.

METHODS

In spring 1999 and 2000 Goldflame honeysuckle liners in 2-inch containers were repotted into 1-gallon containers containing an amended pine park and sand mixture. Plants were grown outdoors in full sun under twice daily overhead irrigation.

Time of application and stage of plant development differed in the two studies, with a late application in 1999 (early June) and an early application in 2000 (late April). Prior to treatment in 1999, plants were advanced (flowering with shoot lengths greater than 36 inches and lower portions of the stems woody). Plants were cut back uniformly before treatment to approximately 12 inches above the substrate and allowed to grow, on average, about 4 inches. Initial shoot lengths were determined on half of the plants and the other half were pruned to 12.4 inches. Following pruning, plants were 3.5 to 4 inches shorter than non-pruned plants. All plants had at least two or three leaves remaining following each pruning. Atrimmec treatments were applied to both non-pruned and pruned plants.

Plants were relatively uniform in shoot length in the 2000 study and were not pruned during the experiment. In 2000, shoot growth was supple, vegetative, or with minimal flowering when Atrimmec was applied. Initial shoot lengths were collected and ranged from 11 to 12 inches. Atrimmec treatments were applied the same day. In both studies, Atrimmec was foliarly applied at 0, 2,340, or 4,680 ppm (0, 1.5, or 3.0 ounces per gallon) to both non-pruned and pruned plants (1999) and non-pruned plants (2000).

Plant shoot length and shoot number were measured at 2-week intervals through 14 weeks after treatment (WAT) in 1999 and through 10 WAT in 2000. Shoots approximately 0.5 inch or more were counted to determine shoot numbers.

Table 1. Shoot Length of Non-pruned and Pruned Goldflame Honeysuckle Through 14 Weeks after Treatment with Atrimmec (1999)

	Shoot length (inches)							
	0 WAT[1]	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	14 WAT
Altrimmec rate (ppm)	Non-pruned						Non-pruned and pruned combined	
0	16.9	28.9	31.6	32.7	35.6	36.4	37.6	39.0
2340	15.6	21.8	25.5	27.8	29.6	30.7	32.2	33.5
4680	16.4	22.9	26.4	29.2	29.8	31.0	29.7	30.7
	Pruned							
0	12.2	21.2	28.1	32.7	35.1	36.9	—	—
2340	12.2	19.4	24.3	28.1	30.8	32.5	—	—
4680	12.2	14.8	18.7	23.4	24.3	26.5	—	—

[1] WAT = Weeks after treatment.

RESULTS

Shoot length suppression. In 1999, Atrimmec suppressed shoot length in both non-pruned and pruned plants. Shoot lengths of non-pruned plants were suppressed by Atrimmec 21 to 25% 2 WAT, 17 to 19% 4 WAT, and 17% 8 and 10 WAT, with the exception of 6 WAT with no evident suppression effects (Table 1). Shoot lengths of pruned plants were suppressed by Atrimmec 10 to 32% 2 WAT, 14 to 34% 4 WAT, 14 to 28% 6 WAT, 13 to 31% 8 WAT, and 12 to 21% 10 WAT. Concurrent pruning suppressed shoot length initially (around 25%) with pruned plants 3.5 to 5 inches shorter than non-pruned plants.

Growth of pruned plants was suppressed to a greater extent than that of non-pruned in non-treated control plants 2 WAT and those treated with 4,680 ppm Atrimmec at 2 through 10 WAT. Pruned, control plants were 26% shorter than non-pruned controls at two WAT. Pruned plants, treated with 4680 ppm Atrimmec, were 36% 2 WAT, 30% 4 WAT, 20% 6 WAT, 19% 8 WAT, and 15% 10 WAT shorter than non-pruned at similar rates. By 12 WAT, pruned plants were similar in shoot length to non-pruned plants resulting from a greater increase in length from pruned plants.

Atrimmec suppressed shoot length 16 to 21% 12 WAT, and 15 to 21% 14 WAT. Between 0 and 4 WAT, shoots grew rapidly with about 16 inches of new growth occurring in control plants (both non-pruned and pruned) and between 7 to 12 inches occurring in Atrimmec treated plants. Growth slowed dramatically following 6 WAT with only 3.2 to 6.7 inches of new growth occurring over the next eight weeks. Based on observations, deceleration in growth between 4 and 6 WAT corresponded with the first flowering event in non-pruned plants. Flowering in pruned plants was delayed around 2 weeks compared to non-pruned and a similar deceleration in growth occurred in pruned plants between 6 and 8 WAT.

Throughout the 2000 study, shoots of plants treated at the lower Atrimmec rate were consistently longer than those of control plants at all sampling events. Shoot lengths of plants treated at the 4,680 ppm rate were 17% 2 WAT, 23% 4 WAT, 21% 6 WAT, 21% 8 WAT, and 20% 10 WAT shorter than those of control plants (Table 2).

Shoot number. In 1999 shoot number at 2 and 4 WAT was not affected by either pruning or Atrimmec (Table 3). Following 6 WAT through 10 WAT, both Atrimmec and pruning affected shoot number. Shoot number of plants treated with Atrimmec increased 44 to 105% 6 WAT, 18 to 68% 8 WAT, and up to 24% 10 WAT. Pruned plants had slightly fewer shoots than non-pruned at these sampling dates for decreases of 26% 6 and 8 WAT and 16% 10 WAT. This decrease in shoot number for pruned Goldflame honeysuckle was not visibly distinguishable and would not likely be discernable to the consumer. Shoot numbers collected following 10 WAT misrepresented actual plant branching due to leaf drop on lower portions of the plant caused by powdery mildew and is, therefore, not presented. In 2000, Atrimmec increased shoot number up to 62% 2 WAT, 46 to 106% 4 WAT, 9 to 27% 8 WAT, and 57 to 66% 6 WAT (Table 4).

Effects of Atrimmec on shoot length suppression differed in 1999 and 2000. The difference was likely associated with pruning (prior to application, allowing regrowth, concurrent with application, or not at all) and with plant stage of development at treatment. Plants in the 1999 study were treated later in the growing season (early June) and were more advanced (plants were consistently flowering with shoot lengths greater than 36 inches, and lower portions of plant had become woody). Following pruning in 1999, new shoot growth occurring in late May and in June was less supple and did not readily twine around plant stakes. In contrast, plants in the 2000 study were treated earlier (late April) and were supple and vegetative at treatment.

In 2000, shoot length suppression was achieved with only the highest Atrimmec rate, while shoots of plants treated with 2,340 ppm Atrimmec were generally longer than those of non-treated plants. Overall, shoot length suppression at the 4,680 ppm rate in 2000 resulted in shoots on treated plants 18 to 24% shorter than non-treated. This suppression was similar to the suppression observed for shoots of non-pruned plants in 1999 (11 to 20%) and some-

Table 2. Shoot Length of Non-pruned Goldflame Honeysuckle 0 Through 10 Weeks after Treatment with Atrimmec (2000)

Altrimmec rate (ppm)	Shoot length (inches)					
	0 WAT[1]	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT
0	11.5	25.1	40.1	45.1	46.9	47.2
2340	11.1	26.1	45.3	50.6	53.2	53.9
4680	11.8	20.9	30.7	35.6	36.8	37.9

[1] WAT = Weeks after treatment.

Table 3. Shoot Number of Non-pruned and Pruned Goldflame Honeysuckle Treated with Atrimmec at 2, 4, 6, 8, and 10 Weeks after Treatment (1999)

	Shoot number				
	2 WAT[1]	4 WAT	6 WAT	8 WAT	10 WAT
Non-pruned	11	14	33	33	34
Pruned	10	16	25	25	29
Altrimmec rate (ppm)					
0	10	16	18	22	29
2340	9	14	26	26	27
4680	11	16	40	37	36

[1] WAT = Weeks after treatment.

Table 4. Shoot Number of Non-pruned Goldflame Honeysuckle 2 Through 10 Weeks after Treatment with Atrimmec (2000)

	Shoot number				
Altrimmec rate (ppm)	2 WAT[1]	4 WAT	6 WAT	8 WAT	10 WAT
0	8	15	21	33	40
2340	8	22	35	36	42
4680	13	31	33	42	51

[1] WAT = Weeks after treatment.

what less than observed for shoots of pruned plants (28 to 33%). In 2000, the lack of suppression at the 2,340 ppm Atrimmec rate may be attributed to the increased vigor of plants treated in April compared to plants treated in June. At the time of Atrimmec application in the 2000 study, all plants were vegetative and non-treated plants grew rapidly in the following 4 weeks until flowering began extensively. In the 2000 experiment, non-treated control plants grew, on average, 28.7 inches, in 4 weeks compared to 15.4 inches in non-pruned plants (1999) and 16.4 inches in pruned plants (1999).

In summary, extensively pruning plants before a later (June) Atrimmec application and pruning just prior to a later (June) application are options for growers to increase the market window of Goldflame honeysuckle through the summer. Therefore, overgrown and woody shoots of Goldflame honeysuckle can be cut back and treated with Atrimmec to suppress subsequent shoot growth. A pruning concurrent with Atrimmec at 4,680 ppm increases shoot suppression. The benefit of concurrent pruning combined with the highest Atrimmec rate lasted through 10 WAT for shoot length suppression. Atrimmec increased shoot numbers at 6, 8, and 10 WAT independently, while pruning reduced shoot number by nine shoots 8 WAT and five shoots 10 WAT. In an early season PGR application (April), Atrimmec proved to be effective in suppressing shoot length and increasing tip number without time-consuming pruning.

Shoot Suppression of Goldflame Honeysuckle Using Growth Retardants

L.L. Bruner, G.J. Keever, J.R. Kessler, Jr., and C.H. Gilliam

Lonicera ×heckrottii 'Goldflame' or Goldflame honeysuckle is a semi-evergreen vine characterized by a twining and climbing habit and continuous blooms throughout spring and summer. Goldflame honeysuckle shoots can reach 10 to 20 feet long in a growing season. Based on observations, the growth habit of Goldflame honeysuckle varies over the growing season. New growth in early spring is supple and twines readily. Increases in shoot length occur rapidly under optimal growing conditions. Once a plant has begun flowering extensively, shoot growth rate slows. As the season progresses, older growth on the lower portions of the plant becomes woody and rigid. Even following pruning, new growth occurring later in the season is less supple and does not twine as readily. Often during container production, the plant's rapid growth and twining habit cause problems as plants grow to an undesirable size and intertwine with adjacent plants. Hand pruning is the standard practice for managing honeysuckle shoot length and increasing shoot number. Additionally, early and frequent pruning is necessary to develop compact, full plants. However, pruning is time-consuming, labor-intensive, and often removes desirable foliage and flowers.

B-Nine, Cycocel, and Cutless are plant growth retardants (PGRs) effective in suppressing growth of numerous plant species and may offer benefits in the production, shipping, and marketing of vining crops such as Goldflame honeysuckle. B-Nine and Cycocel are labeled for use on numerous woody plant species in the greenhouse, but not specifically for Goldflame honeysuckle. Only B-Nine is additionally labeled for nursery use. Cutless is a turfgrass growth retardant, but has been effective in suppressing growth of woody and herbaceous species.

The growing retail market compels today's growers to extend production later into the spring and summer or hold plants at a marketable size to meet consumer demand. PGRs have been shown to provide shoot length suppression when used alone or in combination with pruning. The objective of this research was to determine the effects of three PGRs (B-Nine/Cycocel combined and Cutless alone) at different rates on pruned and non-pruned Goldflame honeysuckle.

METHODS

Goldflame honeysuckle liners in 2-inch containers were repotted into 1-gallon containers containing an amended pine bark:sand substrate. Plants were grown outdoors in full sun under twice daily overhead irrigation. Plant stage of development (flowering vs. non-flowering) at the time of PGR application differed in the two studies as a result of pruning. Prior to treatment and pruning in 1999, plants were physiologically advanced (flowering with shoot lengths greater than 36 inches and lower portions of stems woody). Plants were pruned uniformly to approximately 12 inches above the substrate and allowed to grow approximately 4 inches before PGR application. Plants were flowering extensively when pruned and pruning removed all flowers. PGRs were applied foliarly and included B-Nine/Cycocel tank mixes at 2500/1500, 5000/1500, and 7500/1500 parts per million (ppm); Cutless at 15, 30, and 45 ppm; and a non-treated control.

Plants were more uniform in shoot length in the 2000 study and were not pruned before PGR application. Plants were allowed to reach a marketable size (25.5 to 29.5 inches in length) and at least half were in flower by the time of PGR application. PGRs were applied foliarly and included B-Nine/Cycocel tank mixes at 2500/1500 and 7500/1500 ppm; Cutless at 15, 30, and 45 ppm; and a non-treated control.

Shoot length was measured at 2-week intervals through 6 weeks after treatment (WAT); subsequent measurements were at 4-week intervals through 14 WAT in both 1999 and 2000. Shoot length was measured from the substrate surface to the furthest extended shoot tip. Shoot numbers were determined by counting shoots around one-half inch in length.

RESULTS

In 1999, B-Nine/Cycocel was effective in suppressing shoot length in pruned Goldflame honeysuckle throughout the study (Table 1). Shoot length was suppressed by B-Nine/Cycocel; 18 to 30% (2 WAT), 16 to 28% (4 WAT), 24 to 35% (6 WAT), 24 to 34% (10 WAT), and 19 to 33% (14 WAT). Overall, growth rate of plants across treatments slowed dramatically following 2 WAT. The reduction in growth rate following 2 WAT coincided with the onset of flower bud formation and subsequent flowering. In 1999, Cutless was ineffective in limiting shoot growth of Goldflame honeysuckle and treated plants treated were similar in shoot length to untreated controls throughout the study.

In 2000, B-Nine/Cycocel was effective in suppressing shoot length in non-pruned Goldflame honeysuckle be-

Table 1. Shoot Length of Goldflame Honeysuckle 0 Through 14 Weeks after Treatment with B-Nine/Cycocel (1999)

PGR rate (ppm)	Shoot length (inches)					
	0 WAT[1]	2 WAT	4 WAT	6 WAT	10 WAT	14 WAT
Control	16.6	28.0	30.6	37.0	42.4	43.9
B-Nine/Cycocel						
2500/1500	16.5	22.9	25.7	28.0	32.2	35.5
5000/1500	15.6	21.1	23.2	24.2	29.1	29.4
7500/1500	16.2	19.7	22.2	24.1	27.9	32.2

[1] WAT = Weeks after treatment.

Table 2. Shoot Length of Goldflame Honeysuckle 0 Through 14 Weeks after Treatment with B-Nine/Cycocel (2000)

PGR rate (ppm)	Shoot length (inches)					
	0 WAT[1]	2 WAT	4 WAT	6 WAT	10 WAT	14 WAT
Control	27.4	43.4	46.7	48.2	48.5	49.7
B-Nine/Cycocel						
2500/1500	29.1	40.1	43.2	44.9	46.3	47.2
7500/1500	24.8	33.2	35.3	38.5	39.3	40.0

[1] WAT = Weeks after treatment.

ginning 2 WAT and lasting through the remainder of the study (Table 2). Shoot length was suppressed by B-Nine/Cycocel 8 to 24% (2 WAT), 7 to 24% (4 WAT), 7 to 20% (6 WAT), 5 to 19% (10 WAT) and 5 to 20% (14 WAT). As in the 1999 study, the most rapid increase in shoot length for all treatments occurred between 0 and 2 WAT. However, the increase in shoot length was greater in 2000 with increases of 16 inches in control plants compared to 11.5 inches in 1999. At the time of PGR application in the 2000 study around 50% of the plants had begun flowering. By 2 WAT, all plants in the study were in flower. As in 1999, Cutless treatments were not effective in suppressing shoot length in the 2000 study.

In summary, shoot length suppression from B-Nine/Cycocel treatments was successful throughout the 1999 and 2000 studies, while suppression from Cutless treatments was not. These results indicate B-Nine/Cycocel is effective when applied to pruned or non-pruned Goldflame honeysuckle, even when pruning resulted in plants of different physiological stages (non-flowering vs. partially flowering) at treatment. In 1999, B-Nine/Cycocel was applied to pruned, non-flowering plants and in 2000 to non-pruned, partially flowering plants. Suppression from B-Nine/Cycocel treatments in pruned plants ranged from 16 to 35%. Suppression in non-pruned, partially flowering plants was 5 to 24%.

Pruning reproductive shoots in Goldflame honeysuckle changed the stage of plant evelopment, and plants were less advanced and smaller. Based on the results, the pruned Goldflame honeysuckle appeared more sensitive to B-Nine/Cycocel treatments and shoot length suppression was more pronounced. Therefore, B-Nine/Cycocel could be used effectively to suppress Goldflame honeysuckle shoot length when applied to both pruned and non-pruned shoots allowing growers to extend the production window to meet consumer demand or hold plants at a flowering, marketable size.

Recycled Paper Mulch Affects Container Fertilization

J. S. Glenn, C. H. Gilliam, J.H. Edwards, G. J. Keever, and P.R. Knight

Granular herbicides are the primary method of weed control in container nurseries. However, granular application to spaced containers can be inefficient, with up to 80% of the herbicide lost, depending on plant spacing. Many growers have turned to alternative methods of weed control, such as mulches, to reduce the environmental impact of pesticides in runoff water. Previous work has shown a 1-inch mulch of recycled paper pellets (Enviroguard, Tascon Inc., Houston, Texas) to be an effective method for control of prostrate spurge (*Euphorbia supina*). Enviroguard pellets are manufactured by compressing ground newspaper using pelletizing equipment to form extruded paper pellets approximately 0.25 inches in diameter and 1.5 inches in length. These pellets have a carbon:nitrogen (C:N) ratio of about 500:1 and swell to about twice the volume after saturating with water. Topdress fertilization of container grown plants is a common technique used by nursery growers. Application of fertilizer over a paper mulch with high C:N ratio may lead to immobilization of nitrogen (N) and a negative impact on plant growth. The objective of this study was to compare N leaching and immobilization with different methods of fertilizer application when recycled paper pellets are used as weed control mulch.

METHODS

In the first experiment, uniform liners of *Petunia floribunda* 'Midnight Madness' were transplanted on April 29, 1998 into trade gallon containers using a pine bark/sand substrate (7:1, by volume) amended with 5 pounds dolomitic limestone and 1.5 pounds Micromax per cubic yard. A common commercial fertilizer (Osmocote 14-14-14) was applied at 0.3 ounces per container. Treatments included control (topdressed, no mulch), fertilizer applied over (topdressed), or fertilizer applied under 1 inch (5.1 ounces) of recycled paper pellets. Plants were placed on a greenhouse bench and irrigated as needed (every 1 to 2 days) with a microirrigation system that delivered 8.4 ounces of water per container at the rate of 0.25 gallons per minute. Data collected included nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N) levels in leachate 13, 21, 27, and 35 days after planting (DAP). Plants were harvested 48 DAP to determine shoot dry weight, foliar N content, and total N retained by paper mulch.

A second experiment was conducted similarly to the first, except where noted. *Petunia grandiflora* 'Ultra Blue' liners were transplanted on September 18, 1998. The same fertilizer was applied at 0.6 ounces per container. Fertilizer was applied over a 1 inch layer of recycled paper pellets, under the pellets, or incorporated in the substrate. Two non-mulched controls were included with fertilizer topdressed or incorporated in the substrate. Data collected included NO_3-N and NH_4-N levels in leachate 13, 21, 28, and 35 DAP and foliar color and flower number 49 DAP. Foliar color was rated on a 1-5 scale, where 1=yellow, 2=yellowish green, 3=light green, 4=medium green, and 5=dark green. Plants were harvested 56 DAP to determine shoot dry weight, foliar N content, and total N absorbed by paper.

RESULTS

Experiment 1: Leachate N levels. Generally, nitrogen leaching was lowest when fertilizer was applied over the paper mulch. Leachate NO_3-N levels 13 DAP were reduced 87% when fertilizer was applied over the mulch when compared to a non-mulched control treatment (Table 1). Leachate NO_3-N levels 21 DAP and 27 DAP were almost negligible when fertilizer was applied over or under the mulch treatments. Leachate NH_4-N levels followed the same pattern (data not shown). Leachate NO_3-N and NH_4-N levels decreased from 27 DAP and, thereafter, to less than 0.2 ppm, regardless of treatment (data not shown). Dissipation of NO_3-N and NH_4-N may be explained by high temperatures in the greenhouse, which likely accelerated release of the controlled release fertilizer.

Experiment 1: Plant response. Shoot dry weight was suppressed with recycled paper mulch regardless of fertilizer application method (Table 1). The greatest reduction occurred when fertilizer was applied over the mulch, with 70% less dry weight when compared to non-mulched plants, and 53% less when compared to plants grown with the fertilizer applied under the mulch. Neither fertilizer application method caused a significant reduction in foliar N levels when compared to control plants (data not shown). Total N recovered in paper with fertilizer applied over or under mulch treatments was 0.020 or 0.017 ounces N per container, respectively (data not shown), or 33 to 40% of the total N applied. The high C:N ratio of paper pellets explains N immobilization from topdress application; however, recycled paper mulch absorbed almost as much total N even when fertilizer was placed under the mulch. This condition may occur as a result of capillary upward movement of substrate solution, similar to the process that takes place when plants are watered using capillary mat irrigation.

Experiment 2: Leachate N levels. Results of the second experiment generally concured with results in the first

Table 1. The Effects of Recycled Paper Mulch and Method of Osmocote 14-14-14 Application on NO_3-N Levels in Container Leachate and Petunia Shoot Dry Weight (Experiment 1)

Treatments	NO_3-N (ppm)			Shoot dry weight (g)
Method of application	13 DAT[1]	21 DAT	27 DAT	
Over mulch[2]	0.8	0.0	0.2	5.4
Under mulch	2.8	0.2	0.3	11.5
Control (no mulch)	6.3	27.8	1.8	18.1

[1]DAT = Days after planting.
[2] Mulch = recycled paper pellets 1 inch thick.

Table 2. The Effects of Recycled Paper Mulch and Method of Osmocote 14-14-14 Application on NO_3 -N Levels in Container Leachate, Petunia Shoot Dry Weight, Foliar Color, Foliar Nitrogen, and Flower Number (Experiment 2)

Mulch[2]	Fertilizer placement	NO_3-N (ppm)			Shoot dry wt.	Foliar	Foliar N	Flower
		13 DAT[1]	21 DAT	28 DAT	(g)	color	(%	number
Yes	over	0.3	0.7	0.5	1.6	3.1	4.4	3.5
	under	0.8	0.8	1.0	5.0	3.8	4.5	9.5
	incorporated	3.3	1.7	3.1	6.0	4.4	5.1	8.8
No	topdressed	2.9	2.5	2.9	9.8	4.8	4.6	17.3
	incorporated	11.8	12.8	9.3	10.2	4.1	5.5	15.8

[1] DAT = Days after planting.
[2] Mulch = recycled paper pellets 1 inch thick.

experiment. Fertilizer placement over or under the mulch greatly reduced leachate NO_3-N levels on all leaching dates compared to the topdressed, non-mulched treatment (Table 2). Even when fertilizer was incorporated in the substrate, paper mulch reduced NO_3-N levels compared to the incorporated, non-mulched treatment. Additionally, in non-mulched treatments NO_3-N levels were much lower with topdress fertilization when compared to the incorporated fertilizer treatment. These results concur with previous work which showed that a higher N leachate concentration occurred when a controlled release fertilizer was incorporated rather than surface-applied. Leachate NH_4-N levels followed the pattern of NO_3-N leaching (data not shown). After 35 DAP NO_3-N and NH_4-N leachate levels in control treatments declined to less than 3 ppm and were nearly undetectable in treatments with paper mulch (data not shown).

Experiment 2: Plant response. Shoot dry weight was greatest when plants were not mulched, regardless of fertilizer application method (Table 2). Petunia plants were smallest when fertilizer was applied over the paper mulch. Shoot dry weight was 84 or 49% lower when fertilizer was placed over or under the mulch, respectively, compared to topdressed, non-mulched plants. When fertilizer was incorporated in the substrate, paper mulch reduced shoot dry weight 41%, when compared to the non-mulched control.

Foliar color was lightest when fertilizer was placed over the mulch (Table 2). Best foliar color rating occurred when fertilizer was incorporated in the substrate and mulched, or topdressed without mulch. Flower number was lowest when fertilizer was placed over the mulch (Table 2). Although foliar N levels were highest when plants were not mulched and fertilizer was incorporated, all treatments produced plants with foliar N levels well within the recommended range (Table 2).

Nitrogen immobilization by paper mulch was affected by fertilizer placement. For example, topdressing of fertilizer over the mulch resulted in total paper N of 0.022 ounces N per container, or about 23% of the total N applied, while fertilizer incorporation (with mulch) resulted in 0.010 ounces of total N per container in the paper mulch, or about 8% of the total N applied.

In both tests, paper mulch reduced N in leachate and plant growth regardless of fertilizer application method. However, in the second experiment fertilizer incorporation resulted in more N in leachate (both mulched and non-mulched treatments). This work has several implications for the use of recycled paper in container production of nursery crops. First, growers should realize that container nutrition can be affected when paper mulch is used as a weed control alternative, especially if fertilizer is topdressed. Incorporating the fertilizer reduces the amount of N retained by paper. This work also suggests the potential of recycled paper in nutrient remediation of container effluent and the potential to provide an environmentally friendly postharvest mechanism of prolonged fertilization in the landscape by recycling absorbed N. Additional work is currently being conducted to determine the fate of N absorbed by paper mulch.

Influence of Commercial Auxin Formulations on the Propagation of Camellias

Eugene K. Blythe, Terry Denlay, and Jeff L. Sibley

Camellia cultivars continue to be popular landscape plants for the western and southeastern United States, as well as throughout the world. These low-maintenance landscape plants provide color through the fall, winter, and early spring when little else is in bloom. While most *Camellia* cultivars are produced commercially from cuttings, recommendations for appropriate auxin levels can vary greatly. This study was conducted to evaluate some commercial rooting hormones on the rooting of selected *Camellia* cultivars. The study was conducted under production conditions at Monrovia Nursery Company, a west coast wholesale grower.

METHODS

Cuttings of 20 cultivars of *Camellia* were obtained from container-grown production plants at Monrovia Nursery Company in Azusa, California. Semi-hardwood tip cuttings were prepared in early- to mid-May using firm, green wood following the spring flush of growth. Cuttings of *Camellia* hybrid 'Freedom Bell' and *Camellia japonica* cultivars were prepared with a 2-inch stem, two mature leaves (with leaves cut in half), and a leafless node at the base. Cuttings of *Camellia sasanqua* cultivars were prepared with a 2.5-inch stem, three mature leaves, and a leafless node at the base. Knives were used to make all cuts. Cuttings received a quick basal dip into their respective auxin treatments and were placed into 16 x 17 x 2.25 inch polypropylene cutting flats containing a 1:9 (by volume) peat/coarse perlite medium.

The three auxin treatments used in the trials were (1) Dip 'N Grow™ liquid diluted 1:9 (v/v) with a 50% methanol solution, providing 1000 ppm IBA and 500 ppm NAA; (2) Dip 'N Grow™ liquid diluted 1:3 (v/v) with a 50% methanol solution, providing 2500 ppm IBA and 1250 ppm NAA; and (3) Hormex No. 3 powder, providing 3000 ppm IBA. There were 200 cuttings per replicate (cutting flat) and 20 replicates per treatment per cultivar.

Cutting flats were placed in a randomized order on outdoor, concrete rooting beds in Azusa, California, with 70°F bottom heat (supplied through June only) and 55% shade provided by overhead shade fabric. Cuttings received overhead mist using Spraying Systems 1/4 E5 parasol nozzles with an 8-second duration and varying frequency (manually reset as needed during daylight hours for once every 6 to 60 minutes, depending on ambient temperature and wind, in order to keep cuttings slightly moist). Overhead mist was discontinued after five months to acclimate the rooted cuttings. Rooting percentages were determined after one additional month. Cuttings were considered rooted if the root systems were judged large enough to endure hand potting and subsequently provide high survivability and growth in liner pots.

RESULTS

Rooting percentages among the three treatments varied from one cultivar to another (see table). Cuttings of *Camellia* hybrid 'Freedom Bell' (considered a more challenging cultivar to root) produced the best results (52%) with Dip 'N Grow™ 1:9. Cuttings of *Camellia japonica* 'Chandleri Elegans Variegated' and 'Elegans Splendor' rooted best (77 to 81%) using Dip 'N Grow™ 1:3 and Hormex No. 3. Cuttings of *Camellia japonica* 'Colonel Fiery', 'Glen 40', and 'Silver Waves' produced better rooting percentages (76 to 79%) with Dip 'N Grow™ 1:3 than with Hormex No. 3, but only slightly higher than Dip 'N Grow™ 1:9.

Cuttings of *Camellia japonica* 'Debutante' and 'Spellbound' (two of the easier-to-root cultivars) rooted at 90% or higher for all three treatments, while 'Elizabeth Dowd Silver' rooted close to 80% for all three treatments. Cuttings of *Camellia japonica* 'Daikagura Variegated' and 'Magnoliaeflora' produced the highest rooting percentages with Hormex No. 3, as did 'Nuccio's Pearl' and 'Pink Parade', although some differences were quite close. Cuttings of *Camellia japonica* 'Nuccio's Jewel' and 'Shiro Chan' rooted best with Dip 'N Grow™ 1:9 and Hormex No. 3.

Cuttings of the *Camellia sasanqua* cultivars (which are typically easier to root than *Camellia japonica* cultivars) produced rooting percentages that were quite similar among the three treatments, with the exception of 'Hana-Jiman' for which Dip 'N Grow™ 1:3 produced notably better results.

While general guidelines on the selection of commercial auxin formulations for cutting propagation of woody ornamentals are useful as a starting point, commercial propagators should not assume that that a single product or concentration is optimal for all cultivars within a genus, such as *Camellia*. With several *Camellia* species and so many cultivars in the trade, a clear-cut consensus as to the best auxin formulation and rate is not readily available. Also, the treatment that is optimal for the propagator at one nursery may not be optimal for the propagator at another nursery due to other factors that influence the rooting of cuttings, such as stock plant source, condition of cutting wood, time of year, propagation environment, etc. Some cultivars may respond equally well to a range of auxin treatments, allowing the propagator to select the product and concentration that is most economical, both in terms of product cost and efficiency of use. However, in cases where cultivars exhibit varying responses to certain auxin treatments, propagators may wish to select the treatment that provides the best rooting response. In addition to rooting percentage, this optimal rooting response may also be determined by the size of the root systems, uniformity of root development, amount of callus, and other factors that may affect further development of the newly rooted plants. By conducting trials with commercially available auxin formulations, nursery propagators may select the optimal treatments for their specific cultivars, growing conditions, and propagation environments.

Average Rooting Percentages for Cuttings of 20 *Camellia* Cultivars Treated with Commercial Auxin Formulations

Cultivar	Dip 'N Grow™ 9:1	Dip 'N Grow™ 1;3	Hormex No. 3
Camellia hybrid 'Freedom Bell'	52.4	39.7	39.5
Camellia japonica 'Chandleri Elegans Variegated'	62.0	76.8	81.2
Camellia japonica 'Colonel Fiery'	72.3	75.9	69.6
Camellia japonica 'Daikagura Variegated'	65.8	65.6	74.9
Camellia japonica 'Debutante'	89.6	89.9	93.6
Camellia japonica 'Elegans Splendor'	63.8	78.2	81.1
Camellia japonica 'Elizabeth Dowd Silver'	77.8	77.4	80.6
Camellia japonica 'Glen 40'	72.5	77.9	66.6
Camellia japonica 'Magnoliaeflora'	60.5	69.9	75.4
Camellia japonica 'Nuccio's Jewel'	78.9	64.6	74.7
Camellia japonica 'Nuccio's Pearl'	77.0	73.8	83.5
Camellia japonica 'Pink Parade'	83.2	86.5	95.2
Camellia japonica 'Shiro Chan'	68.5	57.4	67.5
Camellia japonica 'Silver Waves'	75.8	79.3	68.3
Camellia japonica 'Spellbound'	95.4	93.8	95.3
Camellia sasanqua 'Bonanza'	91.4	88.8	88.7
Camellia sasanqua 'Hana-Jiman'	74.5	84.6	75.0
Camellia sasanqua 'Kanjiro'	90.9	92.0	92.5
Camellia sasanqua 'Shishi Gashira'	90.9	86.4	88.7
Camellia sasanqua 'Showa-No-Sakae'	90.8	83.6	87.8

Effect of Liming Source on the Growth and Nutrition of Dwarf Nandina

J. L. Mayfield, J.L. Sibley, E.H. Simonne, and D.J. Eakes

Preplant incorporation of pulverized dolomitic limestone ($CaCO_3/MgCO_3$) is an accepted practice at nurseries all across the United States. As well as neutralizing acidity, and thereby raising pH of container growing media and earthen soil, lime is also the main source of fertilizer calcium (Ca) and magnesium (Mg) for plants. Although limestone is a minor expense compared to other nursery supplies, potential nutritional and economical benefits may be gained from use of liming materials other than traditional carbonate limestone (dolomite) on some ornamental species by providing a more water soluble Ca and Mg fertilizer source.

Soilless media chemistry is different from that of earthen soil, and in recent years, research has questioned the need for limestone in container media mixes, with most container-grown plants able to grow in soilless media at a pH much lower than the pH range required for plants growing in mineral soils (pH 6 - 7).

For some ornamental species, such as azalea, amending the growing media with limestone has been shown to reduce marketable quality and growth. However, past studies have shown a positive response to liming for other nursery crops, among these dwarf nandina (*Nandina domestica* 'Nana Purpurea'). Therefore, dwarf nandina was selected as the test plant for our studies evaluating alternative liming materials.

METHODS

This study was conducted at the Paterson Greenhouse Complex, Auburn University, Alabama, with separate tests initiated on August 17, 1999 for year one and April 14, 2000 for year two. Uniform liners of dwarf nandina were divided into eight lime treatments. Treatments consisted of six different liming materials, gypsum ($CaSO_4 \cdot 2H_2O$), and an unlimed control.

The six treatments were (1) standard pulverized dolomitic limestone, (2) calcium oxide (96% CaO), (3) an oxide-based high calcium limestone blend (45% CaO, high Ca and 97% $CaCO_3$, 50:50 mix by weight), (4) an oxide-based dolomitic limestone blend (24% CaO and 20% MgO and 97% $CaCO_3$, 50:50 mix by weight), (5) commercial grade pelletized dolomitic limestone, and (6) hydrated lime ($Ca(OH)_2$). Lime treatments were based on their respective calcium carbonate equivalence (CCE) values relative to standard pulverized dolomitic limestone (Table 1). Gypsum, though not a liming material, was used to provide the same amount of Ca for uptake as the CaO treatment for comparison (Table 2). Plants were potted into trade gallon pots in a 6:1 pinebark:sand medium amended with 15.6 pounds per cubic yard Osmocote 18-6-12 and 1.5 pounds per cubic yard Micromax (O.M. Scotts Co., Marysville, Ohio) and placed under overhead impact irrigation.

Table 1. Calcium Carbonate Equivalent Values of the Six Treatments

Treatment	Calcium carbonate equivalent
Standard pulverized dolomitic limestone	63
Calcium oxide	172
An oxide-based high calcium limestone blend	130
An oxide-based dolomitic limestone blend	122
Commercial grade pelletized dolomitic limestone blend	63
Hydrated lime	135

Plants were harvested March 15, 2000 for the first study and November 28, 2000 for the second study, approximately seven months after test initiation in each case. On March 15, data were collected for marketable quality ratings (MQR) on a scale of 1 to 5, with 1 being poor growth and foliar color, and 5 being lush, full growth and commercially desirable foliar color. Growth index (GI) [(height + $width_1$ + width perpendicular to $width_1$)/3], shoot nutrient conncentration (SNC), and plant dry matter (% DM) were determined. For dry matter determination, plants were severed at the soil-line and plant material dried at 158°F for 48 hours in a forced-air oven. Samples were ground to pass a 20-mesh sieve, dry ashed, and analyzed for nutrients to obtain N, Ca, Mg, phosphorus (P), potassium (K) and micronutrient (Cu, Zn, Mn, Mo, Fe, B, and Al) foliar concentrations.

RESULTS

Growth parameters. Growth index (GI) and dry matter weight (grams per plant) were higher among all plants during year two. Average GI in year two was 43 compared to 27 in year one, and dry matter weight per plant averaged 2.5 ounces (71 g) for year two and 0.6 ounces (17 g) for year one. Differences were likely due to time of potting and irrigation frequency. For year one, plants were potted in late summer and allowed to grow until early spring 2000. Onset of fall and a subsequent decrease in irrigation frequency during cooler weather limited plant growth compared to year two.

Significant differences existed among treatments for GI, plant quality and dry matter weight in year one (Table 3). Calcium oxide had highest growth parameters overall, though only significant when compared with the high Ca blend, pulverized limestone and $Ca(OH)_2$ treatments. Dry matter weight was 27% higher for CaO, gypsum, and pelletized limestone treatments compared to the control.

For year two, no differences existed among the liming materials, however, all materials resulted in higher GI and dry matter weights than those of the control (Table 3). In this study, regardless of oxide- or carbonate-based liming source, all amendments had positive effects on growth compared to the no-lime control.

Table 2. Liming treatments Calculated to Equal the Calcium Carbonate Equivalence (CCE) of Pulverized Dolomitic Limestone

Lime treatment	—August 18, 1999— CCE[1] value	Rate applied kg/m³	—April 14, 2000— ECCE[2] value	Rate applied kg/m³
Unlimed control	0	0	0	0
Ag. lime	63	3.0	80	3.0
CaO	172	1.1	115	2.1
Dolo. blend[3]	122	1.5	108	2.2
Ca-blend[4]	130	1.4	120	2.0
Gypsum[5]	0	3.3	0	6.4
Pell. lime	63	3.0	69	3.4
Hydrated lime	135	1.4	135	1.8

[1] Calcium Carbonate Equivalence (CCE) is the acid neutralizing capacity of a liming material by weight in relation to pure $CaCO_3$.
[2] Effective Calcium Carbonate Equivalence (ECCE) is CCE X fineness factor for determining acid neutralizing value of a liming amendment.
[3] Oxide-based dolomitic limestone blend (24% CaO and 20% MgO and 97% $CaCO_3$, 50:50 mix by weight).
[4] Oxide-based Ca limestone blend (45% CaO, high calcium and 97% $CaCO_3$, 50:50 mix by weight).
[5] Rate of gypsum calculated to provide the same amount of Ca as CaO.

Table 3. Effect of Liming Source on Growth of *Nandina domestica* 'Nana purpurea'

Liming treatment	—March 2000— Growth index[1]	Dry matter	—November 2000— Growth index	Dry matter	Marketable quality rating[3]
Control	28	16	38	42	3.8
Ag. lime	25	14	45	72	3.1
CaO	31	22	44	78	4.4
Dolo. blend[4]	27	16	44	79	3.5
Ca-blend[5]	26	13	43	71	3.3
Gypsum	28	22	44	79	3.8
Pell. lime	28	22	41	76	3.6
Hydrated lime	24	14	43	72	2.6

[1] Growth index determined by [(height + $width_1$ + width perpendicular to $width_1$)/3].
[1] Dry matter in grams per plant, 28.35 grams equals one ounce.
[3] Marketable quality rating from 1 to 5 with 1 being poor growth and foliar color, and 5 being lush, full growth and desirable foliar colordetermined prior to the March 2000 harvest.
[4] Oxide-based dolomitic limestone blend (24% CaO and 20% MgO, 50:50 mix by weight).
[5] Oxide-based Ca limestone blend (45% CaO, high calcium, 50:50 mix by weight).

Shoot nutrient concentrations and uptake. Highest foliar Ca levels were observed for hydrated lime and lowest levels recorded for the control and both carbonate lime forms (pulverized and pelletized limestone), proving hydrated lime, gypsum, and oxide limes to be more soluble forms of fertilizer Ca. This trend was repeated in year two with the exception that both oxide blends (high Ca and dolomitic) contained leaf Ca concentrations comparable to the unlimed control.

Shoot Mg was highest for pulverized and pelletized limestone treatments in both years. It was expected that dolomitic oxide blend (CaO/MgO) would provide more soluble Mg for uptake, but results from this study did not support this hypothesis.

Calcium oxide, gypsum, and pelletized limestone treatments contained more total foliar nutrients (N, Ca, K, and P) than all other lime amendment treatments and the control in year one. Furthermore, during year one, CaO, gypsum and pelletized lime likewise had highest combined growth parameters (GI, quality, and dry matter weight, data not shown).

The unlimed control had lower uptake of all nutrients (N, Ca, K, Mg, and P) for year two than plants in all liming treatments. Similar trends were found for CaO and gypsum as in year one. Highest Mg uptake was reported for pelletized limestone both years, and highest Ca and K uptake with CaO and gypsum. This is understandable because at the outset of each year, both CaO and gypsum were applied to provide equivalent amounts of Ca (Table 2).

All alternative liming materials resulted in similar or higher growth parameters and foliar nutrient levels compared to pulverized agricultural limestone in both years. Plant growth (GI and dry matter weight) in year two was greater for plants in all liming treatments than those of the unlimed control. In both years, amending growing media with CaO, dolomitic oxide blend (CaO/MgO), gypsum, or pelletized limestone resulted in greater overall growth (GI and dry matter weight) than pulverized limestone and the unlimed control. These treatments, along with the hydrated lime treatment resulted in higher total foliar Ca and Mg uptake compared to the control and pulverized agricultural limestone. Foliar Mg concentration was consistently higher for pulverized and pelletized limestone treatments than for the dolomitic oxide blend, proving the lack of benefit of CaO/MgO blends for improving plant Mg uptake over carbonate forms for dwarf nandina.

Although the cost of CaO is greater than that of dolomitic limestone, the cost of any of the liming materials in this study would only be minor compared to the annual expense of other nursery supplies. Furthermore, this study shows producers may use one-third to two-thirds the amount of CaO compared to dolomite based on CCE (172% compared to 63% for dolomitic limestone). Therefore, economic benefits may exist by changing liming materials for container crops. Likewise, CaO, CaO/MgO blends, gypsum, or pelletized limestone may be more suitable fertilizer sources for Ca and/or Mg than dolomitic limestone.

Coppicing as a Means of Increasing Regular Growth in Chinese Pistache

Melissa R. Miles, Jeff L. Sibley, Gary J. Keever, and Charles H. Gilliam

Chinese pistache (*Pistacia chinensis*) are landscape trees valued by many homeowners for their small size, round-headed shape, fine texture, and striking fall color. The primary non-ornamental use for Chinese pistache is as a rootstock for the edible pistachio nut tree, *P. vera*. Interestingly, few growers have found success budding or grafting ornamental selections of pistache. Consequently, pistache for ornamental purposes are grown from seed, and growers must contend with doglegs, spindly trunks, and irregular early growth. This study was conducted to determine the usefulness of coppicing (a severe cut-back, forcing new growth at the soil line) as a technique for increasing straight, regular trunk growth, and improving overall growth rate of young pistache.

METHODS

Trees used in this study were grown from seed and purchased as Root Maker plugs from Rennerwood Nursery in Tennessee Colony, Texas. Plants were grown for two years in 3-gallon containers under standard nursery conditions. Container substrate was a 6:1 pinebark:sand (by volume) amended with 16.6 pounds of Osmocote 18-6-12, 5 pounds of dolomitic lime, and 1.5 pounds of Micromax per cubic yard.

From November 1999 to April 2000, 24 plants were randomly selected from a block of 500 trees each month and coppiced to 2 inches above the soil line. Stem diameter for all trees averaged 3/4 inches at the point of the cut. No consideration was given to the presence or absence of visible buds on the trunk. A single dominant leader was selected for each plant in all treatments with other sprouts removed May 25 and again July 20. Six months after the final treatment and after the first frost of the fall, plants were examined for mortality rate per treatment and average plant height for living trees.

RESULTS

Trees coppiced in November showed a mortality rate of 29% with an average height of 1.9 feet (data not shown). The trees coppiced in December and January showed mortality rates of 50% and 46% with average heights of 2.2 feet and 2.3 feet, respectively. Trees coppiced in February presented a mortality rate of 38% with heights averaging 1.9 feet. The trees coppiced in March and April showed mortality rates of 33% and averaged heights of 1.5 and 1.6 feet.

While mortality rates ranged from 29 to 50%, the trees used in this study initially did not have acceptable form

Chinese Pistache on the left was coppiced in February 2000, at 2 inches above soil line. The tree on the right is an uncut control of the same age. Desirable straight trunks are an obvious result of severe coppicing when performed at the correct time.

for landscape use and were destined for the compost pile prior to coppicing. Following coppicing, all viable trees were considered marketable, with straight, strong trunks.

Our data indicated that Chinese pistache trees coppiced in November had higher survival rates than all other months with greater height growth than March and April and similar height growth by the end of the growing season to trees pruned in December, January, and February. The greatest losses occurred in December and January with overall height growth for survivors similar to November and February but greater than March and April cut-backs. Further evaluations on field and container grown trees with larger diameter are warranted.

A Southern Classic: Evaluation of *Magnolia Grandiflora* Cultivars

G. Creech, J.L. Sibley, C.H. Gilliam, J.D. Williams, and J.T. Owen

The benefits of tree evaluations at the university level are significant. Such long-term observations are not often feasible in commercial nurseries primarily concerned with growing and marketing the best-selling plant materials, nor are such plantings likely to occur in a replicated fashion in long-term sites such as arboreta primarily concerned with display of numerous species in limited quantities. Furthermore, environmental conditions change such that long-term field observations are particularly valuable as a reference point for landscape use as opposed to the often rapid and somewhat artificial growth responses available from short-term container studies. In landscapes where the climate permits (generally USDA Zones 6-10) southern magnolias are an automatic choice as symbols of the South, reminiscent of large antebellum homes or property boundary markers of the past.

METHODS

In December 1983, twelve southern magnolia selections were added to a comprehensive tree evaluation project initiated in 1980 including more than 200 kinds of trees. The study was conducted at the Piedmont Substation in Camp Hill, Alabama, in USDA Plant Hardiness Zone 7b in a Cecil gravelly sandy loam soil. Trees were spaced 25 feet apart within rows and 30 feet between rows and no supplemental irrigation was applied except at planting. While trees originated from several nursery sources, all trees were container grown prior to field planting and were of similar size at installation.

A complete fertilizer (13-13-13) was applied at planting and in subsequent years in early spring at 1 pound of nitrogen per 1 inch of caliper. Weed control consisted of two applications per year of Roundup or Gramoxone for post-emergence weed control and a spring application of Surflan at 4 pounds per acre for pre-emergence weed control. Herbicides were applied as directed sprays around the tree base in a 4 to 6 foot diameter. While all cultivars sustained minimal deer damage in the first year, no other pruning occurred on the trees. Growth rates were determined by recording tree height, canopy width, and caliper (measured at 12 inches above the soil line) at the end of each growing season.

Leaf size and color evaluations were conducted in September 2000 on ten recently matured leaves of each tree, harvested three nodes behind terminal buds on lateral branches. A portable Minolta Spectrophotometer (CM-2002) was used to rank in a non-subjective manner the difference in the color of the underside of the leaves among each selection.

RESULTS

In general, the seedling selections from a native population near Mobile, Alabama, and 'Margaret Davis' demonstrated the greatest overall growth based on total height, caliper, and canopy width, with height on 'Smith Fogle' being similar to these cultivars (see table). Least overall height growth was for 'Little Gem' and 'Majestic Beauty'. 'Hasse' with a canopy width of 11.6 feet and 'Little Gem' with a canopy width of 13.9 feet demonstrated the most narrow form, which is a trait expected when designers place these cultivars in landscape settings. Likewise, 'Hasse' had a smaller caliper than all other selections in the study with the exception of Aldridge, 'Little Gem', and 'Majestic Beauty', which were similar.

Overall, the *Magnolia grandiflora* seedlings, included as representatives of the species, were among the most aggressive growers in the study, but were highly variable from tree to tree in form, leaf morphology and anatomy, and canopy density, all of which might be expected from seedling magnolias. Only one seedling in our study was attractive enough for commercial potential with few if any unusual or outstanding characteristics evident in the other seedlings.

A selection from Aldridge Nursery (now Von Ormy Growers, Inc.) in Von Ormy, Texas, was included in our study as a seedling strain under the name Aldridge. The

Aldridge strain was selected over a number of years by the late R.C. Aldridge based on blooming at a young age, typically one year to 18 months. There was little variability in growth characteristics of the Aldridge trees in this study and blooming began in the second year of the study (1985). We also noticed an extended blooming season with the Aldridge trees, often extending through the end of July; however, the foliage has consistently been the lightest green of all selections and leaf drop during stress was common. Three unnamed, numbered selections (SG#4, SG#5, and SG#6) were included from Shady Grove Plantation in Orangeburg, South Carolina. SG#5 has since been released as the cultivar 'Smith Fogle'. 'Smith Fogle' has an attractive ovate-pyramidal form with dense brown backs to leaves that are dark green and larger than SG#4 and SG#6. Leaf drop, a common concern among magnolia selections was similar to other cultivars. SG#4 has been dropped from production by Shady Grove, and SG#6 is still in production at Shady Grove but at this point has not been registered as a cultivar.

One of the most attractive trees in the study was 'Hasse' with a narrow upright form, small leaves with dark brown backs, and unusually good leaf retention throughout the year. 'Little Gem' also has good leaf retention with dark brown backs on a small deep green leaf. While height through 1999 has reached around 24 feet for this dwarf selection, 'Little Gem' has a bunchy, shrub-like form as if it was top-pruned. 'Little Gem' has the longest blooming season of all trees in our study, with sporadic blooms from May through the fall.

Based on our observations and the data from this study, 'Glen St. Mary' and 'Bracken's Brown Beauty' are worthy of the popular acclaim and the widespread use they enjoy in our industry. 'Glen St. Mary' has a large brown-backed leaf that tends to hang downward revealing veins more evident on the leaf surface than most other cultivars. The canopy is broad and dense with a pyramidal form making it one of the best selections for landscapes needing a large magnolia. 'Bracken's Brown Beauty' is truly beautiful with upright leaves exposing the velvet brown undersides and with upper leaf surfaces dark green where visible. The canopy is dense, very symmetrical, somewhat upright and ovate and also would easily be one of the better choices for large spaces.

'Claudia Wannamaker' has an attractive form well suited for large spaces with a medium growth rate compared to other cultivars in this study (Table 1). The foliage is decent, but with only dusty-green to light brown undersides to leaves. 'Margaret Davis' with a broad, open canopy could also be used where a large growing magnolia is needed. The leaves have light brown undersides, not outstanding but somewhat attractive.

Perhaps the least attractive cultivar in this study was 'Majestic Beauty'. The leaves of 'Majestic Beauty' were the largest of any in the study, but were also the lightest green of all but the Aldridge strain. Also, the growth habit of 'Majestic Beauty' overall was irregular, lacking any particular characteristic form. Finally, the often redeeming value of many cultivars—a brown back to the foliage—was lacking; 'Majestic Beauty' had pale green undersides. The seedling selections and 'Majestic Beauty' had the largest leaves overall and 'Little Gem' had the smallest leaves. Cultivars 'Bracken's Brown Beauty', 'Hasse', and 'Little Gem' had the most tomentose ("brown" by industry standards) backs, considered highly desirable. 'Majestic Beauty', seedlings, Aldridge, and 'Smith Fogle' leaf undersides were the most glabrous, generally regarded as an undesirable trait in industry.

These trees have developed into excellent specimens in spite of being grown under low-maintenance field conditions. The Auburn University Shade Tree Study site continues to be maintained for grower observations, seed collection, and tours. However, due to the remote location, about 25 miles from campus, visits must be scheduled ahead of time in most cases.

Comparison of Growth and Foliage Characteristics of *Magnolia grandiflora* Selections

Selection [1]	Height[2]	Caliper[3]	Canopy width[4]	Hue rank[5]	Leaf size rank[6]
Aldridge	25.9 ef	8.5 de	18.0 e	9	4
'Bracken's Brown Beauty	26.5 ef	9.3 cd	19.7 cde	2	6
'Claudia Wannamaker'	30.8 bcd	9.0 cd	21.8 bc	7	11
'Glen St. Mary'	26.0 ef	9.4 cd	21.0 bcd	7	5
'Hasse'	29.9 cd	7.0 e	11.6 f	3	8
'Little Gem'	24.4 f	8.2 de	13.9 f	1	12
'Majestic Beauty'	24.1 f	7.7 de	18.4 de	10	1
'Margaret Davis'	34.6 a	12.8 a	26.2 a	4	9
Seedling	35.3 a	12.2 ab	25.6 a	9	2
Shady Grove #4	31.3 bc	10.2 c	20.4 bcde	5	10
Shady Grove #6	28.3 de	10.5 c	23.0 b	6	7
'Smith Fogle' (SG#5)	32.8 ab	10.7 bc	22.2 bc	8	3

[1] Aldridge is a seedling strain from Von Ormy, Texas; Seedlings are from a native population near Mobile, Alabama; numbered selections are from Shady Grove Plantation, South Carolina.; and other cultivars are from various nursery sources. Means are not considered different if followed by the same letter.
[2] Height in feet following 16 years of growth (December, 1983 through Dec., 1999).
[3] Caliper measurements in inches taken at 12 inches above soil line.
[4] Canopy width in feet determined by (East West width) + (North South width)/2.
[5] Trees were ranked based on darkest to lightest pubescence on underside of leaf with 1 being the darkest brown and 10 being the most green (there were two ranked equal at 7 and also at 9); and for leaf size, 1 being the largest leaf and 12 being the smallest leaf.
[6] Leaf area determinations (cm^2) based on average values for ten leaves per tree with three trees per cultivar in each of three replications.

Chilling Durations Affect Foliar Budbreak of Linden (*Tilia* spp.) Cultivars

Barrett C. Wilson and Jeff L. Sibley

Lindens are large, deciduous shade trees (50 to 80 feet tall and 25 to 50 feet wide) found in much of the northern hemisphere, with species native to North America, Europe, and Asia. They produce exceptional shade with dark green leaves and a stately, beautiful form. There are around 10 cultivars of American linden (*Tilia americana*) (USDA Zones 3b-8), 23 cultivars of littleleaf linden (*T. cordata*) (USDA Zones 3b-7), and five cultivars of silver linden (*T. tomentosa*) (USDA Zones 4-7), the species used in this study. Of the readily available cultivars, few have gained popularity in the southern United States, probably because of the prevailing belief that lindens are northern trees with poor performance in the South.

The influence of chilling temperatures in the dormant season on fruit producing trees is widely known. However, there is less understanding of the influence of chilling on ornamental trees. The objectives of this study were to determine if selected linden species and cultivars have differential responses to chilling and to estimate the chilling requirement for the selections. From this information, a model for regional planting recommendations can eventually be constructed to assist in the selection of lindens suitable for southern landscapes.

METHODS

Tissue-cultured plants of *Tilia cordata* Greenspire® and Fairview™, *T. tomentosa* 'Sterling', and *T. americana* 'Redmond' were obtained as 4- to 5-foot tall, bare-root whips in February, 1999. Trees were potted into 7-gallon containers in a pinebark:sand (6:1 by volume) substrate amended with 5 pounds dolomitic limestone, 1.5 pounds Micromax, and 11.1 pounds of 18-6-12 Osmocote per cubic yard. Trees were grown in full sun with overhead irrigation for 10 months in Auburn, Alabama (32° 36NN x 85° 29NW, USDA Hardiness Zone 8a) until December, 1999.

The study consisted of six durations of chilling (chilling considered as total hours below 45°F) applied in increments of 200 hours to each cultivar (200 to 1200 hours). Upon natural accumulation of 200 hours of chilling in December 1999, the first group of plants was placed in a glass greenhouse maintained at a minimum of 72°F. Subsequent groups of trees were placed in the greenhouse at chilling accumulation intervals of 200 hours and were weeded and watered by hand as needed. Plants in treatments 1 through 4 (200 to 800 hours) were allowed to accumulate natural chilling. Plants in treatments five through six (1000 to 1200) accumulated 925 hours of natural chilling through March 2000 with the remainder added while stored at 38°F in a thermostatically controlled cooling unit because of warming temperatures outdoors. By the termination of the study in April 2000, heat units (heat units were total hours of 72°F) accumulated in the greenhouse ranged from 2,856 for treatment one to 504 for treatment six.

After placement in the greenhouse, trees were monitored twice weekly for foliar budbreak. The total number of buds was counted for the top 12 inches of terminal branches, from which percentage budbreak was determined throughout the study. Budbreak was considered to be the point where overlapping bud scales began to separate, revealing leaf tips. The highest budbreak count recorded for each cultivar by the end of the study was assumed to be the highest possible number attainable for this study.

RESULTS

In all cultivars, the rate of foliar budbreak was accelerated by increasing the level of chilling. Increased chilling reduced the number of heat units required to initiate budbreak. Littleleaf linden Greenspire® did not exhibit any foliar budbreak unless chilled for at least 600 hours. The optimal chilling range began at 800 to 1,000 hours, with 20 to 50% budbreak occurring after accumulation of 600 to 1,700 heat units. Fairview™ produced minimal budbreak after 400 hours of chilling, with an optimal range of 800 to 1,000 hours and 30 to 75% budbreak following 600 to 1,700 heat units. 'Sterling' silver linden performed well when chilled at least 600 hours with an optimal chilling range of 600 to 1,200 hours, producing between 60 to 90 % budbreak after 400 to 1,800 heat units. 'Redmond', an American linden, exhibited sparse budbreak after only 200 chilling hours, with the optimal chilling range occurring from 400 to 1,200 hours. However, 'Redmond' showed lower budbreak percentages (20 to 70%) than all other selections evaluated in the 400 to 1,800 heat unit range.

Further study is needed to determine absolute chilling requirements for the various linden cultivars. The work presented here indicates that littleleaf lindens Greenspire® and Fairview™ have the highest chilling requirement of the selections evaluated. 'Sterling' silver linden demonstrated the lowest chilling requirement and the highest budbreak percentage of all selections across all treatments evaluated.

Following termination of the greenhouse portion of this study, all trees were moved back to the growing area outdoors to allow observation of subsequent growth. By the end of the growing season in the fall of 2000, differences observed in initial budbreak were magnified. Trees within each cultivar that had received greater amounts of chilling were larger than trees receiving less chilling. Furthermore, overall growth was greater on 'Sterling' than other cultivars, with the least overall growth occurring for 'Redmond'.

This study indicates the need to carefully select lindens suitable for the region in which they will be grown, whether in field or container production or in the landscape.

Producing Shade Tree Liners in Containers for the Bare Root Market

Ken M. Tilt, Jeff L. Sibley, Floyd M. Woods, Arnold W. Caylor, and Charles P. Hesselein

A major marketing avenue for nursery crops, bare root tree field production, has declined in the past 10 to 15 years. What was once a profitable mainstream production method for many nurseries has declined due to increasing demand for year-round planting and the greater flexibility of container production to meet that demand. Bare root plants are primarily used for liner production in today's nursery production scheme. With increasing global markets and demand for exporting nursery crops, higher fuel prices and shipping costs, as well as increased production costs and shortage of labor, bare root production still has a niche in the nursery business.

Because field production of nursery tree liners requires cutting of roots to harvest trees, container production of bare root liners with roots intact may offer a better alternative for liners destined for container production or transplanting to the field. Bare root trees for the landscape would offer obvious weight and space reduction for shipping compared to equivalent sized container trees. Bare root trees are also desirable and/or required for export to many countries. Furthermore, if bare root trees offer similar transplant success and growth in the landscape compared to equal-sized container trees, they would provide a new niche for nursery producers.

The objectives of this study were to (1) compare bare root tree production in 5-gallon containers using Profile™ (a commercial, non organic, kiln fired, calcined clay ceramic aggregate medium, Aimcor, Denver, Colorado) with traditional container-grown trees using a pinebark:peat container medium; (2) compare the effects of root pruning of bare root liners to non-root pruned liners potted in containers to simulate the current practice of using pruned, bare root field-dug liners; (3) observe the relative ease or difficulty of removing trees bare root from containers containing the Profile medium; and (4) evaluate the effects of storing, transporting, and transplanting trees to a landscape site to compare the survivability and growth of traditional container trees with the bare root trees.

METHODS

On April 1, 1998, 72 container-grown bare root liners (18 to 36 inches tall) of *Ulmus americana* 'Liberty' (Elm Research Institute, Harrisville, New Hampshire) were planted in 5-gallon RootMaker™ Grounder (Lacebark, Inc., Stillwater, Oklahoma) containers at the Ornamental Horticulture Station in Mobile, Alabama. RootMaker containers were selected because of numerous small drainage holes which prevents the fine particles of Profile from leaching out the bottom of the container. Prior to planting, one-half of the trees were root pruned with approximately 50% of the roots removed to simulate bare root tree liners from the field. Elms were planted in two media: Profile or a 4:1 pinebark:sphagnum peat moss medium (v/v). Profile was previously used successfully as an amendment to container media. Media were amended with 1.5 pounds per cubic yard Micromax, (O.M. Scotts, Marysville, Ohio). Pinebark medium included 5 pounds per cubic yard of dolomitic limestone. Lime was omitted from the Profile medium due to its inherent high pH. Media were topdressed with 4.2 ounces Osmocote fertilizer 15-9-11 (O.M. Scotts, Marysville, Ohio). Containers were arranged in a production area at the Auburn University Mobile Ornamental Horticulture Station.

Irrigation was applied to each container using Bosmith pressure compensating spray stakes (Maxi-Jet, Acuff Irrigation Company, Cottondale, Florida). Initial irrigation volume was adjusted by determining the average daily water loss (ADWL) for each medium and replacing that water in equal volumes divided into three irrigation cycles per day at 10 a.m., 1 p.m., and 4 p.m. Irrigation volumes were adjusted throughout the growing season due to plant growth and environmental conditions.

Plants were harvested and measured for height and caliper on February 26, 1999. Profile was easily removed from roots by gentle shaking. Used Profile media was collected in a central area for reuse in the next production cycle. Bare root trees were placed in plastic bags and stored in a cooler at 38°F for 8 weeks until planting at the North Alabama Horticultural Station (NAHS) in Cullman, Alabama on May 3, 1999. Twelve container and 36 bare root trees were planted 15 feet on center in a landscape setting to evaluate the survival and growth of the trees after transplanting. Height and caliper were measured on January 25, 2000.

RESULTS

Elms grown in the Profile medium in 1998 had greater height (7.6 feet) than those grown in the pinebark:peat medium (6.3 feet) (see table). There was no difference detected when comparing pruned and unpruned treatments within the Profile medium or between the unpruned treatments of Profile and pinebark based media. Pruning method or media type did not affect caliper among the treatments. Profile medium had a high pH ranging around 7.5. Also, some of the elms grown in Profile medium appeared chlorotic. There was 100% survivability following transplant of the 36 bare root plants and the 12 container plants after one year in the landscape. Caliper growth of transplanted trees was greater in the container/pinebark based medium (1.3 inches) at the end of the 1999 growing season than the bare root/Profile grown trees (1.0 inches). There was no difference in height for the trees planted bare root or in containers. Trees were 8.8 feet and 8.7 feet tall for container and bare root elm trees, which represented a mean increase over the growing season of 2.7 feet and 1.2 feet respectively. Height of root-pruned container liners after one year in the landscape (8.4 feet) narrowed the height deficit between the non-pruned trees (9.1 feet) to a difference that was not significant.

Although new Profile medium was used in the study, physical properties of some previously used Profile were compared with the new medium. No differences were found between them for each of the properties evaluated including airspace (12.4 and 15.0%), water-holding capacity (40.5 and 39.6%), total porosity (53.0 and 54.6 %), and bulk density (0.53 and 0.51 g/cm^3) for new and used media, respectively. It is important to be able to reuse the material due to the cost.

Table 1. Height (in Feet) of Pruned and Unpruned Liners Grown in Profile or Pinebark Based Media

	Profile	Pinebark
Pruned	7.5 a[1]	5.5 b
Unpruned	7.7 a	7.1 a

[1] Means with different letters within columns represent significant differences.

The results of this research offer evidence of a potential niche market for production of bare root trees in containers which can be successfully stored, exported, and/or transplanted to the landscape with similar growth results to other methods. Reduction in growth of root pruned elm liners in the pinebark based media suggests potential increased growth of container bare root liners over field-grown root pruned liners. Further research is needed with additional species to verify this conclusion. Container size, root pruning treatments, or time-in-production adjustments need to be investigated for several species, including aggressive rooting species, to evaluate the ease of Profile or other media removal from roots. Experience with river birch trees (*Betula nigra*) under similar conditions resulted in root bound trees that could not be separated from the Profile medium.

Liner production is currently in great demand in the nursery industry. An increased global demand for nursery products also requires roots to be free of soil and organic material. This research shows potential for bare root production of trees or other plants in containers where 100% of the roots are left intact for storage and shipping. Shipping and handling costs of less bulky and lighter weight trees along with improved establishment and growth of the plants in the landscape or nursery are potential benefits from growing bare root plants in containers with Profile or similar medium.

HERBACEOUS ORNAMENTALS

Root Mass and BA Affect Offset Formation in Hosta

Heather C. Schultz, Gary J. Keever, J. Raymond Kessler, Roland R. Dute, and John W. Olive

Outgrowth of axillary and rhizomic buds (offset formation) in hosta is inhibited by apical dominance, a process regulated by an internal balance between auxins and cytokinins. Root loss during division and potting can alter hormonal balance, thus affecting shoot growth. When water is a limiting factor, apical dominance is stronger. Reduced water supply from roots also limits leaf expansion and shoot growth.

Benzylandenine (BA) is a synthetic cytokinin, which promotes elongation of inhibited buds, including offset formation in hosta. Although BA-induced offset formation is a fast and effective method for propagating hosta, results have often been highly variable. In previous studies, plants were graded primarily for shoot uniformity and secondarily for root uniformity. Loss of roots, which occurs in crown division, without a reduction in shoot size, results in water stress and has a detrimental impact on many metabolic processes necessary for growth. In addition, lack of water availability is a limiting factor for the outgrowth of inhibited buds. The role of root mass and its interaction with BA on offset formation in hosta has not been examined; therefore, the objective of this study was to determine the effects of root mass and BA on offset formation in hosta.

METHODS

Stock plants of 'Francee', a cultivar that readily forms offsets, and 'Frances Williams', which forms offsets more slowly than 'Francee', were divided into single-eye plants, in Auburn, Alabama. This experiment was repeated at the Ornamental Horticulture Station in Mobile, Alabama. Divisions were grouped according to root mass (RM = small, medium, and large) and potted in 1-gallon pots. When surface root development was evident, ten plants of each cultivar from each root mass group were sprayed with 3,000 ppm BA (+BA). Offsets were counted 30 and 60 days after treatment (DAT).

RESULTS

When treated with BA, large RM 'Francee' formed 50 and 85% more offsets at 30 DAT and 52 and 81% more offsets at 60 DAT than the medium and small RM groups of the same cultivar, respectively. For the -BA 'Francee', medium RM plants produced more offsets than large RM plants at 30 DAT, but offset counts were similar among all

Table 1. Root Mass and BA Effects on Offset Number in Hosta 30 and 60 Days After Treatment, Mobile, Alabama

Root mass class	Offset number		
	'Francee'		'Frances Williams'
	30 DAT[1]	60 DAT	60 DAT
	+BA		
Small	4.7	4.7	3.1
Medium	6.2	5.6	5.4
Large	8.7	8.5	4.5
	-BA		
Small	1.2	3.7	2.0
Medium	2.3	3.2	1.3
Large	0.6	2.7	1.0

[1] DAT = Days after treatment.

RM groups at 60 DAT. Differences among RM groups in 'Frances Williams' were not significant at 30 DAT; however, across all RM groups, +BA plants produced 4.0 offsets compared to 0.3 for the -BA plants. The +BA medium RM 'Frances Williams', produced 74% more offsets than small RM plants at 60 DAT, and a similar number as the large RM plants (Table 1). For 'Francee', the +BA plants produced more offsets than corresponding -BA plants in each RM group at 30 DAT (small = 292%, medium = 170%, large = 1,350%) and at 60 DAT for the medium and large RM plants. At 60 DAT 'Frances Williams' offset numbers were higher in +BA plants with medium (315%) or large (350%) RM than in corresponding -BA plants.

At the Mobile location, the number of offsets for 'Francee' increased as RM increased for +BA plants at 30 DAT and for -BA plants at 60 DAT. At 60 DAT, +BA plants with large RM produced considerably more offsets than plants with small RM, but counts were similar to plants with medium RM. Plus BA 'Francee' with medium (3,900%, 30 DAT) or large (2,450% and 73%, 30 and 60 DAT, respectively) RM produced more offsets than small corresponding -BA 'Francee'. Large RM 'Frances Williams' produced more offsets than the small or medium RM plants at 30 and 60 DAT (small, 0.3; medium, 0.4; large, 1.2), but only in +BA plants at 30 DAT (Table 2). Compared to corresponding -BA plants, offset numbers were higher for +BA 'Frances Williams' plants with medium or large RM at 30 DAT and across all RM groups at 60 DAT (+: 1.0, -: 0.2).

Generally, regardless of BA application, offset formation was positively correlated with increasing RM in both cultivars, although the greatest differences were noted between large RM and medium or small RM groups. BA was effective in inducing outgrowth of axillary and rhizomic buds in hosta, but the response was often more evident in plants with medium or large RM than in plants with small RM, possibly due to greater water uptake. Ensuring adequate RM at the time of division and potting enhances hosta's response to BA, resulting in increased offset production. In addition, larger RM was correlated with larger whole plant size. All of these responses should contribute to minimizing growing time.

Table 2. Root Mass and BA Effects on Offset Number in Hosta 30 and 60 Days After Treatment, Auburn, Alabama

Root mass class	Offset number: 'Francee' 30 DAT[1]	Offset number: 'Francee' 60 DAT	Offset number: 'Frances Williams' 60 DAT
+BA			
Small	0.0	1.3	0.6
Medium	4.0	3.3	0.7
Large	10.2	6.9	2.4
-BA			
Small	0.2	1.5	0.1
Medium	0.1	3.2	0.0
Large	0.4	4.0	0.3

[1] DAT = Days after treatment.

Benzyladenine (BA) can stimulate outgrowth of rhizomic and apical buds, but the response to BA is affected by root mass. Application of BA to divisions with minimal root mass is less effective; therefore, growers should ensure adequate root mass at division or allow sufficient time for root mass development prior to BA application. Information on the effects of root mass on hosta's response to BA provides valuable insight into developing a system for the accelerated propagation of hosta.

BA Application Timing Affects Offset Formation in Hosta

Heather C. Schultz, Gary J. Keever, J. Raymond Kessler, and Roland R. Dute

Outgrowth of buds in hosta leading to offset formation is inhibited by apical dominance, a process regulated by an internal balance between auxin and cytokinins. Benzyladenine (BA) is a synthetic cytokinin effective in promoting elongation of inhibited buds, including offset formation in hosta. Plants with no offsets at the time of BA application produced more offsets than plants with multiple offsets. These offsets could be removed and rooted under intermittent mist. The percentage of offsets that rooted and survived was positively correlated with the number of unfurled leaves on the offsets. BA response was cultivar dependent, and additional applications of BA were necessary to continue the positive response to BA after offset removal.

Although BA-induced offset formation has been a fast and effective method for propagating hosta, the role of potting date relative to treatment date has not been examined. In previous studies conducted at Auburn University, BA application was delayed until surface roots were present at the substrate-container interface, approximately 4 weeks after potting. However, when BA was applied shortly after potting in a commercial nursery, minimal stimulation of offset formation occurred. The objective of this study was to examine the effects of timing of BA application relative to division and potting on offset formation in two hosta cultivars.

METHODS

The two cultivars selected for this study, *Hosta* 'Francee' and *H. sieboldiana* 'Frances Williams', are widely used in the landscape; however, 'Frances Williams' forms fewer offsets than 'Francee'. On May 7, 1997, stock plants of each cultivar were divided into single-eye plants and potted into 1-gallon pots using an amended pinebark:sand medium. A 3,000 ppm BA solution (+BA) was foliarly applied once to each group of plants at 0, 1, 2, 3, 4, 5, or 6 weeks after potting (WAP). Offsets for controls and plants that had received a BA application were counted 6 weeks after potting (WAP), and 30 and 60 days after the last BA treatment was applied (DALT). The experiment was repeated in 1998 using similar methodology. Offsets for each BA application and controls were counted 30 and 60 days after each treatment was applied (DAT).

RESULTS

In 1997, plants treated 1, 2, or 3 WAP produced 187 to 287% more offsets than plants treated at potting (Table 1). Plants treated 4 or 5 WAP produced similar numbers of offsets as those treated at potting. The lack of positive response in plants treated 4 or 5 WAP was probably due to data being collected just 1 or 2 weeks after treatment and plants not having as long to respond to BA as plants treated 1, 2, or 3 WAP. Offset number increased with BA at

Table 1. BA Application Timing Comparisons Across Cultivars For Offset Number 6 Weeks after Potting, and 30 and 60 Days after Last Treatment (1997)

BA application timing WAP[1]	Offset number: 6 WAP	30 DALT[2]	60 DALT
0	1.5	4.5	5.5
1	5.0	5.0	4.8
2	4.3	4.5	5.5
3	5.8	5.9	6.6
4	1.0	5.8	6.1
5	1.5	6.4	6.7
6	—[3]	6.8	6.7
Control	1.4	3.3	3.7

[1] WAP = Weeks after potting.
[2] DALT = Days after last treatment.
[3] BA treatment not applied until after data collection.

Table 2. BA Application Timing Comparisons within Cultivar and Cultivar Comparisons within BA Treatment for Offset Number 30 and 60 Days after Treatment (1998)

BA application timing	Offset number: 'Francee'		'Frances Williams'	
WAP[1]	30 DAT[2]	60 DAT	30 DAT	60 DAT
0	2.2	4.0	0.5	0.9
1	3.0	4.5	0.9	2.0
2	4.6	5.0	0.5	0.6
3	9.2	9.2	1.1	1.3
4	7.2	8.9	0.8	1.0
5	7.1	8.3	2.3	2.5
6	8.9	9.7	1.3	1.7
Control	1.4	2.8	0.2	0.6

[1] WAP = Weeks after potting.
[2] DAT = Days after treatment.

application at increasingly later times 30 and 60 DALT. At 30 DALT, plants treated 3 or more WAP produced 29 to 51% more offsets than plants treated at potting. At 60 DALT, plants treated 3 or more WAP produced 11 to 22% more offsets than plants treated at potting, probably due to insufficient root development needed to support shoot growth. Compared to control plants, plants treated with BA at 1, 2, or 3 WAP produced 207 to 314% more offsets 6 WAP (Table 1). By 30 DALT, plants treated 3 or more WAP produced 79 to 106% more offsets than control plants.

In 1998, offsets for 'Francee' plants increased with BA application at increasingly later times—30 and 60 DAT—which agrees with the results from 1997 (Table 2). Plants treated 2 or 3 WAP produced 109 to 318% more offsets, respectively, than plants treated immediately after potting at 30 DAT. The 60 DAT response was not as strong as that at 30 DAT, but plants treated 3 or more WAP produced 107 to 143% more offsets than plants treated at potting.

'Francee' plants treated 2 or more WAP produced 229 to 557% more offsets than control plants 30 DAT, and plants treated 3 or more WAP produced 196 to 246% more offsets than controls 60 DAT (Table 2). 'Frances Williams' +BA plants treated 3, 5, or 6 WAP produced 1.1 to 2.3 offsets, while controls produced 0.2 offsets at 30 DAT. These results were similar to 1997 results and reinforced that BA stimulates rapid offset formation within 30 DAT when applied to established division. But, due to the normal rate of offset formation over time in controls, the difference in offset numbers between treated and non-treated plants is decreased. 'Francee' produced 209% to 820% more offsets than 'Frances Williams' 30 DAT for plants treated 2 to 6 WAP (Table 2), and 125 to 800% more offsets 60 DAT for plants treated 0 to 6 WAP.

BA-induced offset formation is an effective method to accelerate propagation of hosta; however, BA is most beneficial when plants are allowed to establish prior to application. Although this establishment period is usually 3 or 4 weeks after potting in the South, the establishment period is cultivar dependent. A good indicator of root establishment is evidence of surface root development. Results of this study support previous work conducted in which BA was not applied until plants were established. Allowing plants to establish prior to BA application will increase hosta's response to BA by increasing offset formation, which results in higher rooting percentages and minimizes cropping time.

Benzyladenine Improves Summer Quality of Hosta

Heather C. Schultz, Gary J. Keever, J. Raymond Kessler, Jr., and Roland R. Dute

Benzyladenine (BA), a synthetic cytokinin, has been effective in inducing the outgrowth of inhibited buds, including the promotion of lateral shoots or offset formation in hosta. A secondary effect of BA-induced offset formation is that the outgrowth of newly formed offsets often mask the foliage of the mother plant, improving overall plant appearance.

By midsummer hostas grown in the southern United States often experience a condition referred to as summer dormancy. This condition is characterized by foliar chlorosis and necrosis and reduced plant vigor, leading to increased susceptibility to diseases and insects and lower plant quality. If declining foliage is overshadowed by a flush of new growth, the spring market might be extended into summer or fall and landscape quality during the summer improved.

The objective of this study was to promote foliage development in several hosta cultivars/species with BA both during container production and in the landscape, thus enhancing summer quality and landscape value.

METHODS

Container production. Stock plants of *Hosta* 'Sum & Substance', *H. sieboldiana* 'Elegans', *H. plantaginea, H.* 'Francee', *H. sieboldiana* 'Frances Williams', and *H.* 'Tokudama' were divided into single-eye plants and potted on June 30, 1998. Plants were grown under 47% shade and irrigated for 30 minutes twice per day. On August 20, 1998, when plants were showing symptoms of summer decline (foliar chlorosis/necrosis and reduced vigor), half the plants of each cultivar were sprayed with 3000 ppm BA (Pro-Shear). Offset number and a quality rating (QR) were recorded 30 and 60 days after treatment (DAT).

Landscape application. 'Francee' and 'Frances Williams' plants grown in 1-gallon containers with 0 to 2 initial offsets were planted in ground beds on June 30, 1998. Plants were grown under 47% shade and irrigated for 30 minutes twice daily. Plants were allowed to establish and grow until symptoms of summer decline appeared. At that time, some plants had produced additional offsets; therefore, offsets were counted on each plant. 'Francee' plants were placed in groups with either two, three, or four initial offsets. 'Frances Williams' plants had either zero, two, or three initial offsets. On August 21, 1998, half of the plants in each offset group from each cultivar were sprayed with 3,000 ppm BA. Offset number and QR were recorded 30 and 60 DAT.

RESULTS

Container production. More offsets were produced by plants treated with BA than by controls in 'Sum & Substance', 'Elegans', 'Francee', and 'Tokudama' (Table 1). Among +BA plants, 'Sum & Substance' and 'Elegans' produced more offsets than 'Frances Williams' or *H. plantaginea*. Offset number was not influenced by cultivar for control plants, probably due to the low numbers of offsets formed by all cultivars. Across cultivars, plants treated with BA produced 467% more offsets than controls (Table 2). Across BA treatments, 'Sum & Substance', 'Elegans', 'Francee', and 'Tokudama' produced more offsets than 'Frances Williams' and *H. plantaginea* (Table 3).

'Sum & Substance' and 'Elegans' +BA plants had an 88 and 82%, respectively, higher QR than corresponding controls 30 DAT (Table 1). In the presence of BA, *H. plantaginea* had a higher QR than all cultivars, except 'Elegans'. In the absence of BA, *H. plantaginea,* 'Frances Williams', 'Francee', and 'Tokudama' had a higher QR than 'Elegans' and 'Sum & Substance'. *H. plantaginea* is a species that is more heat tolerant than the cultivars tested, as evidenced by its high QR for both +/-BA treatments. It grows readily in USDA Hardiness Zone 9,

Table 1. Hosta Cultivar/Species and BA Effects on Offset Number and Quality Rating, 30 Days After Treatment During Container Production of Hosta

Cultivar/Species	BA[1]	Offset number	QR[2]
'Sum & Substance'	+	3.9	3.0
'Elegans'	+	2.8	3.5
plantaginea	+	0.6	4.4
'Frances Williams'	+	0.6	2.9
'Francee'	+	1.8	2.0
'Tokudama'	+	2.2	3.0
'Sum & Substance'	-	0.4	1.6
'Elegans'	-	0.2	1.9
plantaginea	-	0.2	3.7
'Frances Williams'	-	0.1	3.1
'Francee'	-	0.0	2.9
'Tokudama'	-	0.2	2.9

[1]Plants either received a foliar application of 3,000 ppm BA (+) or did not (-).
[2] QR = Quality rating: 1 = ≥75% foliar necrosis; 2 = ≥50% but <75% necrosis; 3 = ≥25% but <50% necrosis; 4 = ≥10% but ≤25% necrosis; 5 = ≤10% necrosis.

whereas the cultivars tested are only hardy through Zone 8. At 60 DAT, +BA plants had a 28% higher QR than -BA plants (Table 2). The higher QR appeared to relate to a flush of new growth in +BA plants.

Landscape application. Across initial offset groups, +BA 'Francee' plants produced 475% more offsets than controls 30 DAT (4.6 vs. 0.8) and 543% more offsets than controls 60 DAT (4.5 vs. 0.7, Table 4). 'Frances Williams' +BA plants produced 100% more offsets than controls 30 DAT (0.6 vs. 0.3), and 67% more offsets than controls 60 DAT (0.5 vs. 0.3). This is the first report of BA stimulation of offset formation in an established landscape planting. At 60 DAT, 'Francee' +BA plants had a 21% higher QR than controls (Table 4). There were no effects on QR in 'Frances Williams' 30 or 60 DAT, possibly due to the low numbers of offsets produced in all treatments.

The diverse geographic areas of Japan from which hostas originated account for their versatility in the North American landscape. Depending on the cultivar, hostas can be grown as far south as USDA Hardiness Zone 9; however, many cultivars decline both during production and in the landscape during summer months in Zones 7-9. Summer decline in hosta includes foliar necrosis, reduced vigor, and increased susceptibility to diseases and insects, all of which reduce marketability. Our results suggests that summer quality can be enhanced with summer BA application through increased offset production, reduced foliar necrosis, or both. Improved quality late in the growing season has the potential to enhance marketability of hosta as well as improve the appearance of established landscape plantings.

Table 2. BA Comparison Across Cultivars for Offset Number and Quality Rating, 60 Days After Treatment, During Container Production of Hosta

BA[1]	Offset number	QR[2]
+	1.7	3.5
-	0.3	2.7

[1] Plants either received a foliar application of 3,000 ppm BA (+) or did not (-).
[2] QR = Quality rating: 1 = ≥75% foliar necrosis; 2 = ≥50% but <75% necrosis; 3 = ≥25% but <50% necrosis; 4 = ≥10% but ≤25% necrosis; 5 = ≤10% necrosis.

Table 3. Hosta Cultivar/Species Comparisons Across BA Treatments for Offset Number 60 days After Treatment, During Container Production of Hosta

Cultivar/Species	Offset number
'Sum & Substance'	1.8
'Elegans'	1.3
plantaginea	0.3
'Frances Williams'	0.4
'Francee'	1.1
'Tokudama'	1.2

Table 4. Hosta 'Francee' and 'Frances Williams' BA Comparisons Across Initial Offset Number for Change in Offset Number 30 and 60 Days after Treatment and 'Francee' Quality Rating 60 DAT in a Landscape Evaluation

	'Francee' Change in offset number[1]			'Frances Williams' Change in offset number	
BA[3]	30 DAT[4]	60 DAT	QR[2] 60 DAT	30 DAT	60 DAT
+	4.6	4.5	4.6	0.6	0.5
-	0.8	0.7	3.8	0.3	0.3

[1] Change between 0 and 30 DAT, and between 0 and 60 DAT.
[2] QR = Quality rating: 1 = ≥75% foliar necrosis; 2 = ≥50% but <75% necrosis; 3 = ≥25% but <50% necrosis; 4 = ≥10% but ≤25% necrosis; 5 = ≤10% necrosis.
[3] Plants either received a foliar application of 3,000 ppm BA (+) or did not (-).
[4] DAT = Days after treatment.

BA Does Not Reduce Detrimental Effects of High Night Temperature on Offset Formation in Hosta

Heather C. Schultz, Gary J. Keever, J. Raymond Kessler, Jr., and Roland R. Dute

Foliar applications of benzyladenine (BA), a synthetic cytokinin, induce offset formation in hosta. Although BA-induced offset formation is an effective method for the accelerated propagation of hosta, commercial growers have noted that hosta multiply more slowly in the southeastern United States than in more northern parts of the country, possibly due to higher temperatures, especially at night. The objectives of this study were to investigate the effects of night temperatures on offset formation in hosta and to determine if BA can overcome potential detrimental effects of high temperatures.

METHODS

This study was conducted twice in 1998 using similar methodology. Stock plants of 'Francee' and 'Frances Williams' hostas were divided and potted into 1-gallon pots on April 20 and June 16, 1998 (experiments 1 and 2, respectively) using an amended pinebark:sand medium. Half the plants of each cultivar were sprayed with a 3,000 ppm aqueous BA solution (+BA) (Pro-Shear) at 0.5 gallon per 100 square feet using a CO_2 sprayer. Following treatment, all plants were immediately transferred to growth chambers (May 18 and July 17 in experiments 1 and 2, respectively) where they received a 12-hour photoperiod from incandescent and flourescent lamps and were maintained at 90° F. There were four, 12-hour night temperature regimes: 55°F, 65°F, 75°F, and 85°F. Offset counts and growth were determined at 45 days after treatment (DAT).

RESULTS

Offset number for +BA plants of both cultivars decreased in experiments 1 and 2 as night temperatures increased (Table 1). Plants grown at the three lower night temperatures produced 260 to 360% and 157 to 214% more offsets in experiments 1 and 2, respectively, than plants grown at the highest night temperature. In the absence of BA, night temperature had no effect on offset number in either experiment, probably due to the low number of offsets produced by plants in all temperature treatments. At the three lower temperatures, +BA plants produced 2,050 to 3,500% and 106 to 340% more offsets than -BA plants in experiments 1 and 2, respectively. At the highest night temperature, there was a trend for greater offset formation in +BA than in -BA plants. The similarities in offset numbers produced at the three lower night temperatures, within a BA treatment, indicate a relatively strong tolerance to elevated night temperature in the two hosta cultivars tested. However, BA was not effective in overcoming negative effects of the highest night temperature, 85°F, a summer temperature common for at least part of the night in much of the southeastern United States.

Across cultivars and BA treatment, plant size decreased in both experiments as night temperature increased (Table 2). Compared to that of plants in the lowest night temperature, plants in the highest night temperature were 33 and 20% smaller in experiments 1 and 2, respectively. There were no treatment effects on plant quality in either experiment. Overall, quality was good to excellent for plants of both cultivars in all night-temperature treatments in experiment 1. The general good quality of all plants may relate to the earliness in the growing season that night-temperature treatments were initiated. Quality of both cultivars, but especially 'Frances Williams', was lower in the second experiment. By the beginning of the second experiment, marginal leaf necrosis was present in 'Frances Williams'. This condition is not uncommon on foliage of 'Frances Williams' grown in the southeastern United States.

Table 1. Effect of Night Temperature and BA Application on Offset Number in 'Francee' and 'Frances Williams' Hosta

Offset number				
	Experiment 1		Experiment 2	
Night temperature (°F)	+BA	-BA	+BA	-BA
55	4.3	0.2	3.6	1.4
65	3.6	0.1	4.4	1.0
75	4.6	0.2	3.7	1.8
85	1.0	0.0	1.4	0.8

Table 2. Night Temperature Effects Across Hosta Cultivars and BA Treatments on Growth Index (Experiments 1 and 2)

	Growth index[1]	
Night temperature (°F)	Experiment 1	Experiment 2
55	33.5	29.9
65	30.7	28.0
75	27.4	25.0
85	25.2	24.9

[1] Growth index = (height + widest width + width perpendicular to first width) ÷ 3; in cm.

Results of this study indicate potential negative effects of elevated night temperatures on offset production in hosta and whole plant size. Most of the negative effects occurred only at the highest night temperatures, 85°F, a common summer night temperature in the southeastern United States. Application of BA stimulated offset production at the three lower night temperatures in both experiments, but not at the highest night temperature suggesting BA application is not effective in overcoming potential detrimental effects at night temperatures likely to occur in the southeastern United States.

Chilling Duration Affects Shoot Emergence in Hosta

Gary J. Keever and J. Raymond Kessler

Dormancy, an evolved mechanism which aids in winter survival, has been studied in numerous woody species, especially in fruit trees. Much less is known about dormancy or chilling requirements for herbaceous perennials. One source stated that winter chilling to around 32°F or below for several weeks is required for all hostas. However, there are no published scientific studies showing the chilling requirements for shoot emergence in hosta. Knowledge of chilling requirements in hosta would be beneficial in forcing plants into leaf for spring sales, as well as identifying southern extremes for hosta production from stock plants and for landscape use. The objective of this study was to determine chilling effects on shoot emergence and subsequent growth in two cultivars of hosta.

METHODS

Non-dormant stock plants of two hosta cultivars, 'Frances Williams' and 'Francee', were divided on September 15 ('Frances Williams') and October 9, 1997 ('Francee') into uniform, single eye divisions and potted into full-gallon containers. Prior to exposure to temperatures below 45°F, plants were transferred into a double polyethylene greenhouse with a heat setpoint of 65°F and a ventilation setpoint of 78°F.

On November 26, 10 plants of each cultivar were assigned randomly to each of nine treatments. Treatments consisted of chilling each cultivar for 0, 2, 4, 6, 8, 10, 12, 14, or 16 weeks. Those in eight treatments were placed in a dark cooler set at 39°F. Ten plants of each cultivar remained in the greenhouse.

At two-week intervals, 10 plants of each cultivar were transferred back to the greenhouse. Dates of shoot emergence and first unfurled leaf were recorded. Length and width of first unfurled leaf were measured at first unfurling and multiplied together to obtain a leaf area index (LAI). Emergence of non-chilled plants, which did not defoliate in the greenhouse, was based on visible shoot elongation. Collection of shoot emergence and leaf unfurling data was terminated on April 3, 1998, 57 days after the last group of plants was removed from the cooler. On June 25, 1998 foliage was cut at the substrate surface for dry weight determination.

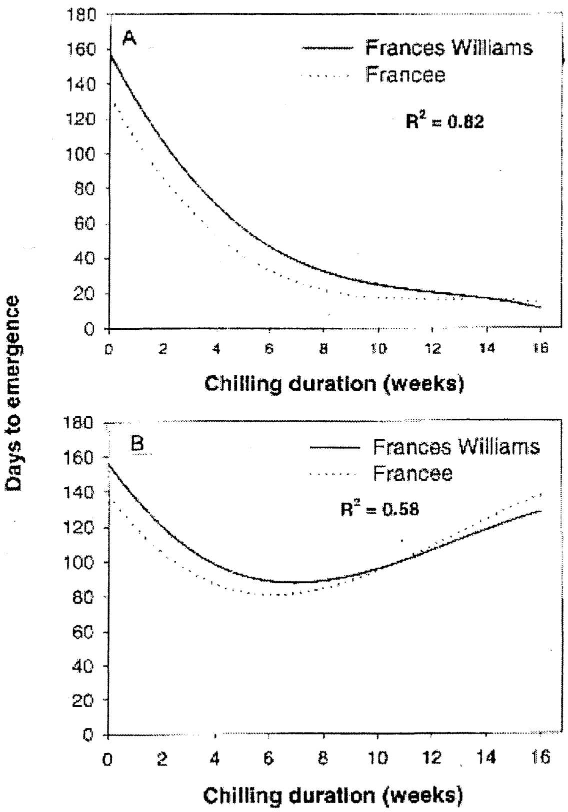
RESULTS

With both cultivars, there was a rapid decrease in days to shoot emergence after about 8 weeks of chilling, followed by a more gradual decrease (Fig. 1a). When days to emergence included both chilling and forcing times, days to emergence decreased with up to 6 to 7 weeks of chilling before increasing (Fig. 1b). The increase in days to emergence represents the influence of longer chilling periods and a diminishing decrease in forcing time by additional chilling. Predicted minimum days to emergence were achieved with chilling periods of 6.2 weeks for 'Francee' and 7.0 weeks for 'Frances Williams'. Including time in the model allows grower to more fully weigh the benefits of shorter forcing times considering the longer chilling periods required.

Days to leaf unfurling followed a similar pattern as days to shoot emergence. In 'Frances Williams' chilled for 0, 2 and 4 weeks, six, three, and five plants, respectively, failed to emerge and eight, three, and one plants failed to unfurl a leaf. In 'Francee' chilled for 0 and 2 weeks, three and one plants, respectively, failed to emerge and six and one plants failed to unfurl a leaf. All plants of both cultivars chilled for longer durations emerged and unfurled at least one leaf. Plants that did not emerge or failed to unfurl a leaf may be a good indicator of minimum chilling requirements.

Based on these data and under the conditions tested, 'Frances Williams' requires a minimum chilling period of 6 weeks. 'Francee' requires less chilling, 2 and 4 weeks for 90 to 100% emergence and unfurling, respectively. However, emergence and unfurling were much more rapid with additional chilling. LAI increased as chilling duration in-

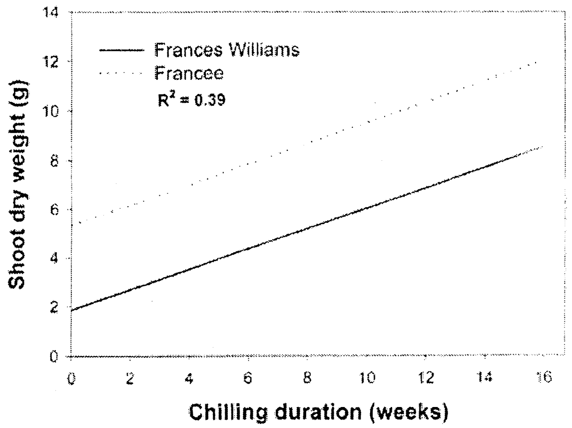
Fig. 1. Effect of chilling duration on days to emergence of two hosta cultivars; (a) Days to emergence after chilling; (b) Days to emergence from the initiation of cooling (includes chilling and forcing times).



creased up to about 12 weeks (data not shown). Shoot dry weight increased in both cultivars as chilling duration increased. 'Francee' plants chilled for 8 and 16 weeks had shoot dry weights 63 and 126%, respectively, higher than that of controls. Corresponding increases in 'Frances Williams' at 8 and 16 weeks were 181 and 361%, respectively (Table 2). Results of this experiment indicate that chilling produced a clear benefit in time to shoot emergence, leaf unfurling, shoot dry weight, and plant vigor to chilling.

Chilling of hosta is beneficial in promoting shoot emergence and more vigorous growth. Information from this study provides growers with guidelines for forcing hostas for early markets, identifying southern extremes for hosta production, and possibly for holding hostas dormant in coolers to force a flush of new growth later in the season.

Fig. 2. Effects of chilling duration on shoot dry weight of two hosta cultivars.



Plant Growth Retardant Application to 'Coronation Gold' Achillea and 'Corrie's Gold' Gaura

Stephanie E. Burnett, Gary J. Keever, Charles H. Gilliam,
J. Raymond Kessler, Jr., and Charles Hesselein

'Coronation Gold' achillea is a grey-foliaged perennial with a rosette growth habit and stately, golden flower heads up to 3 to 4 inches in diameter. However, achillea has the potential to grow 2 to 4 feet in height, and some species grow so quickly that the plant is considered a weed. Gaura is a tough herbaceous perennial native to Texas and Mexico and well suited to survive the hot, humid climate of the Southeast. It has a loose, open, and sprawling growth habit and can grow up to 4 feet tall. Flowers are usually white or pink, with blooms that last from late spring through fall.

As consumer demand for herbaceous perennials increases, the need for information on growing these species becomes more pressing. Many species, including achillea and gaura, grow rapidly; plants often out-grow their pots, become top-heavy and blow-over under nursery conditions, and require frequent watering after becoming pot-bound. Additionally, tall, leggy plants are of lower quality and cost more to ship. Pruning is one option for control of these species; however, it is costly, time-consuming, and may delay flowering. Plant growth retardants (PGRs) have been used on herbaceous species to produce more compact plants, and may offer an efficient means of controlling growth of these species.

B-Nine is labeled for use on herbaceous perennials under greenhouse and nursery conditions. Bonzi is labeled for use in greenhouses, shadehouses, and nurseries on herbaceous perennials as a foliar spray or media drench. Cutless is labeled for use on turf, but not herbaceous perennials; however, previous research has shown it to control growth of many horticultural crops. Pistill is labeled for use on herbaceous perennials in greenhouses and nurseries. The objective of this study was to determine growth responses of 'Coronation Gold' achillea and 'Corrie's Gold' gaura to PGR application in a nursery setting.

METHODS

This study was conducted in an outdoor nursery production area in spring of 1998 and 1999. Methodology was identical for both species over the two years, unless otherwise stated.

In 1998, plants were established from rooted cuttings that were transplanted in fall 1997 into 1-gallon pots containing an amended 3:1 pine bark and peat medium and over-wintered outdoors. On January 26, 1999, achillea and gaura plugs were transplanted in 1-gallon pots containing an amended 7:1 pine bark and sand medium. In both years, plants were spaced pot-to-pot outdoors until treatment. In 1998, achillea were about 12 inches tall when treated and had 5 to15 visible reproductive buds. In 1999, all visible flower buds were removed from achillea just prior to treatment. Gaura were pruned at the time of treatment to a uniform growth index [GI = (height + widest width + width perpendicular to widest width) ÷ 3] of about 13 inches.

PGR treatments, applied as foliar sprays, included the following: B-Nine at 2,500, 5,000, or 7,500 ppm; Bonzi at 33, 66, or 99 ppm; Cutless at 50, 100, or 150 ppm; Pistill at 500 or 1,000 ppm; and an untreated control. Shoot height was recorded for achillea at first flower and when plants were marketable, and GI was recorded for gaura at first flower and at 60 days after treatment (DAT). Plant quality was not determined in 1999 for achillea, or either year for gaura, because treated plants appeared to be similar in quality to non-treated plants. In 1999, height was recorded for achillea, and GI for gaura bi-weekly until the experiment was terminated. The number of days to first flower was recorded for achillea, but not for gaura because plants were in flower shortly after treatment (1-3 days).

RESULTS

'Coronation Gold' achillea. In 1998, growth control from B-Nine was minimal and would not be of practical benefit to most growers. Both Bonzi and Cutless controlled growth and advanced flowering of achillea in 1998. Application of Bonzi decreased height 6 to 17%, 0 to 13%, and 2 to 16% at first flower, when marketable, and at 60 DAT, respectively (Table 1). Bonzi-treated plants bloomed 3 to 6 days earlier, and reproductive buds were 26 to 55% more developed than those of non-treated plants, based on shoot stage rating. Growth was retarded by application of Cutless 13 to 23%, 11 to 17%, and 16 to 24% at first flower, when marketable, and at 60 DAT, respectively. Cutless-treated plants bloomed 4 to 6 days earlier, and their reproductive shoots were 39 to 53% more advanced than those of control plants. Quality of plants treated with Bonzi or Cutless was similar to that of control plants.

In 1998, shoot height was suppressed by increasing rates of Pistill, 8 to 13% and 10 to 12% at first flower and 60 DAT, respectively. Pistill-treated plants were similar in size to non-treated plants at a marketable stage, probably because they reached a marketable stage 5 to 14 days later than control plants. Market quality rating of plants treated with Pistill was lower than for control plants. These plants had fewer and smaller flowers, while foliage was less dense and had considerable chlorotic or necrotic tissue.

In 1999, no PGR delayed time to first flower. Height was consistently suppressed by B-Nine through 70 DAT (Table 2). Control ranges from 25 to 29%, 23 to 37%, 28 to 42%, 16 to 29%, and 25% at 14, 28, 42, 56, and 70 DAT, respectively. Differences in height control between 1998 and 1999 were probably due to the removal of visible reproductive shoots from plants before treatment in 1999. As with B-Nine, applications of Bonzi and Cutless also were more effective in 1999 than in 1998 in retarding plant growth. Growth was suppressed by Bonzi 14 to 25%, 23 to 30%, 30 to 40%, 14 to 29%, and 17 to 30% at 2, 4, 6, 8, and 10 WAT, respectively. Cutless-treated plants were 21 to 29%, 42 to 47%, 46 to 54%, 35 to 49%, and 40 to 51% shorter than control plants at 2, 4, 6, 8, and 10 WAT, respectively. Increased growth suppression in the second year with application of both Bonzi and Cutless may be explained, as for B-Nine, by the less developed reproductive shoots in achillea when treated.

In 1999, height of Pistill-treated plants was suppressed 14 to 19% and 20 to 22% at 28 and 42 DAT. Pistill-treated plants flowered at the same time with similar numbers of inflorescences as control plants and appeared to be of similar quality.

Table 1. Growth and Quality of 'Coronation Gold' Achillea Following Treatment with Several Plant Growth Retardants (1998)

Growth retardant	Rate (ppm)	First flower Days to	First flower Height (cm)	Marketable stage[1] Height (cm)	60 DAT[2] Height (cm)
Control	0	31	48	47	49
B-Nine	2,500	31	48	49	51
	5,000	32	48	49	51
	7,500	27	46	45	46
Bonzi	33	28	45	47	48
	66	25	40	42	42
	99	28	40	41	41
Cutless	50	27	42	42	41
	100	25	42	40	41
	150	26	37	39	37
Pistill	500	31	44	46	44
	1,000	31	42	44	43

[1] Marketable stage: five inflorescence fully open (all florets showing color).
[2] DAT = Days after treatment.

Table 2. Growth of 'Coronation Gold' Achillea Following Treatment with Several Plant Growth Retardants (1999)

Growth retardant	Rate (ppm)	Height (cm) 14 DAT[1]	28 DAT	42 DAT	56 DAT	70 WAT
Control	0	28	43	50	51	53
B- Nine	2,500	21	33	36	43	40
	5,000	22	32	35	43	44
	7,500	20	27	29	36	38
Bonzi	33	24	33	35	44	44
	66	24	32	35	40	40
	99	21	30	30	36	37
Cutless	50	22	25	27	33	32
	100	22	26	27	30	31
	150	20	23	23	26	26
Pistill	500	24	35	40	44	45
	1,000	26	37	39	45	48

[1] DAT = Days after treatment.

'Corrie's Gold' gaura. In 1998, B-Nine had little or no effect on plant size at first flower or 60 DAT (Table 3). In 1999, application of B-Nine suppressed growth 1 to 8% and 2 to 10% at 28 and 42 DAT, respectively; at 56 DAT, B-Nine-treated plants were from 2% larger to 10% smaller than control plants (Table 4). Application of Bonzi did not suppress growth of gaura in 1998 or 1999.

In 1998, Cutless-treated plants flowered at the same time as controls, and there was no significant control of growth at first flower. At 60 DAT, plants treated with Cutless were 13 to 19% smaller than control plants. GI decreased with increasing rates of Cutless in 1999; plants treated with Cutless were 10 to 13%, 7 to 17%, 1 to 12%, and 1 to 11% smaller than non-treated plants at 28, 42, 56, and 70 WAT, respectively. Cutless was the most effective PGR on gaura in both years, and did not delay flowering.

In 1998, Pistill delayed flowering 11 to 13 day. At first flower, Pistill-treated plants were 25 to 30% larger than non-treated plants, presumably because they grew almost 2 weeks longer before flowering. Application of Pistill in 1999 suppressed growth 24 to 26% and 20% at 14 and 28 DAT, respectively. No suppression of growth occured at 42, 56, or 70 DAT.

In conclusion, B-Nine, Bonzi, and Cutless provided increased growth suppression of 'Coronation Gold' achillea with increased concentration. However, plant response to these PGRs appears dependent upon pruning just prior to treatment, which altered stage of development at the time of application. B-Nine did not suppress plants with elongated reproductive shoots (1998); however, it was effective in controlling height of plants without visible productive shoots (1999). Bonzi and Cutless controlled plants containing tall reproductive shoots in 1998 and plants that didn't contain reproductive shoots at time of treatment in 1999. However, both PGRs suppressed growth to a greater degree in 1999. For gaura, Cutless at 100 or 150 ppm was the only PGR to provide adequate control of growth.

Table 3. Growth of 'Corrie's Gold' Gaura Following Treatment with Several Plant Growth Retardants (1998)

Growth retardant	Rate (ppm)	First flower: Days to	First flower: Growth index[2]	60 DAT[1] Growth index
Control	0	25	38	63
B-Nine	2,500	26	42	60
	5,000	26	41	58
	7,500	26	41	67
Bonzi	33	29	43	56
	66	28	42	59
Cutless	50	26	40	55
	100	28	39	53
	150	26	38	51
Pistill	500	36	54	57
	1,000	38	51	62

[1]DAT = days after treatment.
[2] Growth index = (height + widest width + width perpendicular)/3; in cm.

Table 4. Growth Index of 'Corrie's Gold' Gaura Following Treatment with Several Plant Growth Retardants (1999)

Growth retardant	Rate (ppm)	Growth index[1]: 14 DAT[2]	28 DAT	42 DAT	56 DAT	70 WAT
Control	0	54	71	83	90	91
Nine	2,500	54	70	81	92	88
	5,000	49	64	75	83	87
	7,500	49	65	75	81	82
Bonzi	33	52	69	81	91	92
	66	51	70	85	95	92
	99	53	68	81	89	90
Cutless	50	48	64	77	89	92
	100	52	68	70	79	81
	150	47	62	69	81	82
Pistill	500	40	57	71	83	84
	1,000	41	57	75	83	87

[1] Growth index = (height + widest width + width perpendicular) /3; in cm.
[2] DAT = days after treatment.

Growth Regulation of Mexican Sage and 'Homestead Purple' Verbena During Greenhouse and Nursery Production

S. E. Burnett, G. J. Keever, J. R. Kessler, Jr., and C. H. Gilliam

Salvia leucantha (Mexican sage) and *Verbena canadensis* 'Homestead Purple' ('Homestead Purple' verbena) are herbaceous perennials that provide unique additions to many landscapes. Mexican sage produces spikes of attractive purple flowers that envelop the plant in the fall when few other plants are in bloom. Additionally, it is a bee, butterfly, and hummingbird attractant. However, Mexican sage presents a challenge to growers who wish to produce and market the plant in flower because it can grow 3 to 4 feet in a single growing season. Additionally, it is a short-day plant for flowering, and under natural conditions will reach its aesthetic peak in fall. Because most growers transplant plugs or rooted cuttings in the spring, Mexican sage could have a growing season of 5 to 6 months before it is marketed in flower. During this time, it can grow quite large and become difficult to manage in 1-gallon or smaller containers.

Verbena canadensis and its cultivars are some of the most popular herbaceous perennials in the landscape due to their floriferous and durable nature. However, verbena can quickly spread up to 36 inches and often requires repeated pruning or transplanting to a larger pot for maintenance in a nursery or greenhouse environment. For the nursery or greenhouse grower, excessive growth of either Mexican sage or verbena can lead to blow-over, plants outgrowing their pots, excessive drying between irrigations, increased shipping costs, and leggy, unmarketable plants.

Plant growth retardants (PGRs), including Cutless, Sumagic, B-Nine/Cycocel tank mixes, and Pistill, are effective in controlling growth of numerous horticultural crops, including many herbaceous perennials. Sumagic and Cycocel are currently labeled for use on herbaceous species in greenhouses, but not in nurseries outdoors. B-Nine and Pistill are labeled for use on herbaceous perennials in greenhouses and outdoor nurseries. Even though Sumagic and Cycocel are not labeled for use outdoors, many nurseries have double-poly houses or poly-covered cold frames under which these chemicals may be applied. The tank mix of B-Nine and Cycocel is becoming more common due to a synergistic response, providing control in situations where other chemicals alone are less effective. Cutless is labeled for use on turf; however, research indicates that this PGR may be useful in controlling growth of horticultural crops.

Most research examining height control of herbaceous perennials has been conducted under greenhouse conditions with plants in small containers, usually 4 inches or smaller. In the northeastern United States, herbaceous perennials are produced primarily in greenhouses, but in the South they are a mainstay in outdoor nurseries where they are typically produced in containers larger than 4 inches. Personal observation and general literature on the use of PGRs suggest that the effectiveness of PGRs may be less under nursery conditions than in greenhouse production due to differences in plant and pot sizes, physiological stage of plant development at the time of application, irrigation rates, weather, and crop nutrition. Reductions in the effectiveness of PGRs under nursery conditions would require growers to consider using higher rates or multiple applications of PGRs to achieve the desired growth control.

The objective of this study was to determine the growth response of Mexican sage and 'Homestead Purple' verbena to several PGRs under typical greenhouse and nursery conditions in the southeastern United States.

METHODS

Greenhouse study. Rooted cuttings of both species were transplanted in February 1999 to 4-inch pots containing a peat-based medium, placed in a heated double-poly greenhouse, and fertilized. PGR treatments were applied as foliar sprays after plants had approximately 1 inch of new growth. Treatments included Cutless at 50, 100, or 150 ppm; Sumagic at 20, 40, or 60 ppm; B-Nine/Cycocel tank mixes at 2,500/1,500, 5,000/1,500, or 7,500/1,500 ppm, respectively; Pistill at 500 or 1,000 ppm; and an untreated control. At 6 weeks after treatment (WAT), half of the plants in each treatment were planted in outdoor ground beds to determine the persistence of PGR treatments in a landscape setting. Growth index [GI = (height + widest width + width perpendicular)÷3] was determined at 2-week intervals, starting at 2 WAT, until treatment effects were no longer significant.

Nursery study. Mexican sage were transplanted in March 1999 from 4-inch pots to 1-gallon pots containing an amended pine bark:sand medium. Plants were placed outdoors in full sun and received overhead irrigation twice daily. Commercial plugs of verbena were transplanted to 1-gallon pots containing the same substrate in October 1998 and over-wintered pot-to-pot outdoors. On April 11, verbena were pruned 2 inches outside the pot rims, and on May 7, Mexican sage were pruned 8 inches above the pot rims. The same PGR treatments used for the greenhouse portion were applied to the plants in 1-gallon pots on May 18. Similar data were collected as in the greenhouse study; however, plants were not transplanted into the landscape.

RESULTS

Greenhouse: Mexican sage. Increasing rates of all PGRs reduced GI of Mexican sage through 6 WAT in the greenhouse (Table 1). Across all rates, Cutless suppressed GI by 0 to 10%, 7 to 14%, and 0 to 9% at 2, 4, and 6 WAT, respectively, compared to controls. With Sumagic, GI was 10 to 15%, 10 to 17%, and 3 to 12% less than that of controls at 2, 4, and 6 WAT, respectively. GI was10 to 15%, 24 to 28%, and 24 to 26% less for plants treated with B-Nine/Cycocel tank mixes compared to controls at 2, 4, and 6 WAT, respectively. Finally, for Pistill, GI was suppressed 20 to 30%, 17 to 28%, and 12 to 18% at 2, 4, and 6 WAT, respectively, compared to GI of non-treated plants. Of the rates tested, Cutless and Pistill were most effective in suppressing growth at the highest rates, Sumagic was equally effective at 40 and 60 ppm, and all rates of B-Nine/Cycocel tank mixes provided similar control.

After Mexican sage were transplanted into ground beds, GI of plants treated with Cutless or Sumagic was not different from that of non-treated plants at 2 WAP. GI of plants treated with Pistill was 8 to 11% less than that of non-treated controls 2 WAP, but similar at 4 WAP. Growth index of plants treated with B-Nine/Cycocel was different from that of non-treated controls for the greatest length of time; at 2 WAP, plants were 17 to 25% smaller than controls, and at 4 WAP, treated plants were 6 to 21% smaller. By 6 WAP in the landscape, growth retarding effects of B-Nine/Cycocel were not present. Lack of persistent growth control with Cutless, Sumagic, Pistill, and to a lesser extent, B-Nine/Cycocel tank mixes after plants were transplanted into the landscape indicates consumers can expect normal growth following purchase of plants treated with these PGRs.

Greenhouse: 'Homestead Purple' verbena. All PGRs retarded shoot growth at 2, 4, and 6 WAT (Table 2). Cutless reduced GI 4 to 17% and 8 to 15% at 2 and 6 WAT, respectively, and treatment effects were non-significant by 2 WAP in the landscape. Sumagic retarded GI 13 to 21% and 10 to 18% at 2 and 6 WAT, respectively, and 15 to 23% at 2 WAP, but its effect was non-significant at 4 WAP in the landscape. B-Nine/Cycocel tank mixes suppressed GI 25

Table 1. Growth Index[1] of Mexican Sage Following Treatment with Several Plant Growth Retardants in the Greenhouse and after Transplanting Outdoors into Ground Beds

Growth retardant	Rate (ppm)	Greenhouse 2WAT[2]	4 WAT	6 WAT	Landscape 2 WAP[2]	4 WAP
Control	0	20	29	34	36	47
Cutless	50	20	27	34	38	47
	100	20	26	33	36	48
	150	18	25	31	34	46
Sumagic	20	18	26	33	35	47
	40	17	24	30	35	45
	60	17	24	31	35	47
B-Nine/	2,500/1,500	17	22	26	30	44
Cycocel	5,000/1,500	18	21	26	31	42
	7,500/1,500	17	21	25	27	37
Pistill	500	16	24	30	33	43
	1,000	14	21	28	32	47

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment; WAP = weeks after planting in ground beds; 2 WAP corresponded to 8 WAT.

Table 2. Growth Index[1] of 'Homestead Purple' Verbena Following Treatment with Several Plant Growth Retardants in the Greenhouse and after Transplanting Outdoors into Ground Beds

Growth retardant	Rate (ppm)	Greenhouse 2WAT[2]	4 WAT	6 WAT	Landscape 2 WAP[2]	4 WAP
Control	0	24	35	40	40	44
Cutless	50	23	33	37	36	45
	100	21	33	35	34	43
	150	20	30	34	36	43
Sumagic	20	21	31	35	34	45
	40	20	32	36	33	44
	60	19	30	33	31	46
B-Nine/	2,500/1,500	18	28	33	33	42
Cycocel	5,000/1,500	17	25	31	30	41
	7,500/1,500	18	26	32	31	41
Pistill	500	20	29	36	41	45
	1,000	16	24	32	32	42

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment; WAP = weeks after planting in ground beds; 2 WAP corresponded to 8 WAT.

to 29%, 20 to 29%, and 18 to 23% at 2, 4, and 6 WAT, respectively. At 2 WAP this combination still provided control, with an 18 to 25% growth suppression compared to non-treated plants; however, at 4 WAP, treatment effects were non-significant.

Pistill suppressed growth 17 to 35%, 17 to 31%, and 10 to 20% at 2, 4, and 6 WAT, respectively, compared to non-treated plants. It was the only PGR that caused a delay in flowering at 4 WAT; 20% of plants treated with the low rate and 80% of plants treated with the high rate of Pistill were not in flower at 4 WAT while all control plants were flowering. By 4 WAP, GI was similar for Pistill-treated and control plants.

Nursery: Mexican sage. As in the greenhouse, increasing rates of all PGRs reduced GI at 2 WAT, but only Cutless and B-Nine/Cyccocel tank mix provided significant GI reduction through 4 WAT (Table 3). No significant growth suppression occurred 6 WAT with any PGR. Thus, a single application of any of these PGRs at the rates tested would not provide extended control of growth in a nursery environment, where the need for height control may be greater than in greenhouses due to problems with blow-over.

Nursery: 'Homestead Purple' verbena. Under nursery conditions, only Sumagic significantly reduced shoot growth at 2 WAT (Table 4), and none of the PGRs suppressed GI thereafter. The minimal reduction in GI provided by Sumagic at 2 WAT (0 to 10%) would be of limited benefit in controlling the growth of this sprawling perennial.

In conclusion, under greenhouse conditions, all of the PGRs provided excellent size control of Mexican sage. Conversely, all of the PGRs reduced Mexican sage GI at 2 WAT under nursery conditions, but only Cutless and B-Nine/Cycocel tank mix suppressed growth 4 WAT. By 6 WAT in a nursery setting, no PGR reduced the size of Mexican sage. The difference in 'Homestead Purple' verbena's response to PGRs in the two locations was more dramatic. All PGRs provided adequate control through 6 WAT in the greenhouse. Sumagic provided minimal control only at 2 WAT in the nursery, but no other PGR provided control of growth in that location. This research shows that PGRs have good growth retarding effects under greenhouse conditions, but under nursery conditions their effects are less persistent and vary with species treated.

Table 3. Growth Index[1] of Mexican Sage Following Treatment with Several Plant Growth Retardants in the Nursery

Growth retardant	Rate (ppm)	–Growth index– 2 WAT[2]	4 WAT
Control	0	42	56
Cutless	50	39	50
	100	38	52
	150	35	48
Sumagic	20	40	53
	40	38	55
	60	37	52
B-Nine/	2,500/1,500	38	55
Cycocel	5,000/1,500	37	50
	7,500/1,500	33	46
Pistill	500	35	53
	1,000	30	50

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment.

Table 4. Growth Index[1] of 'Homestead Purple' Verbena Following Treatment with Several Plant Growth Retardants in the Nursery

Growth retardant	Rate (ppm)	Growth index 2 WAT[2]
Control	0	31
Cutless	50	30
	100	27
	150	30
Sumagic	20	31
	40	29
	60	28
B-Nine/	2,500/1,500	31
Cycocel	5,000/1,500	29
	7,500/1,500	31
Pistill	500	27
	1,000	28

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment.

Growth Regulation of Russian Sage During Greenhouse and Nursery Production

S.E. Burnett, G.J. Keever, C.H. Gilliam, and J.R. Kessler, Jr.

Perovskia atriplicifolia (Russian sage) is a grey-foliaged herbaceous perennial that produces terminal flower panicles throughout the summer, is well suited to dry sites, and has no photoperiod or vernalization requirement for flowering. Despite its redeeming landscape characteristics, Russian sage is a rapidly growing perennial that can reach 5 feet in height in one growing season, and it is often difficult to maintain in greenhouses and nurseries. Excessive growth can lead to blow-over in nurseries, plants out-growing their pots, reduced plant quality, and increased shipping costs.

Plant growth retardants (PGRs) can be an economical option for controlling growth, and often these chemicals also improve the quality and overall appearance of many plants including herbaceous perennials. B-Nine, Cycocel, Pistill, and Sumagic are labeled for use on herbaceous perennials in the greenhouse; B-Nine and Pistill may also be used in nurseries. B-Nine and Cycocel are often applied as tank mixes, and the synergistic combination of these two chemicals appears to be one of the most effective chemical growth controls currently available. Cutless is labeled for use on turf; however, it has been effective in controlling growth of other horticultural crops.

Under greenhouse conditions, plants are usually grown in 4-inch or smaller pots, watered only as necessary, receive fertilizer as periodic liquid feed, and are not exposed to the rigors of unpredictable weather. In the nursery, plants are grown in 1-gallon or larger pots, watered according to the demands of a schedule and surrounding plants, receive time-released nutrients, and endure outdoor weather. Any of these conditions could result in a difference in plant response to PGRs. The objective of this experiment was to determine the growth response of Russian sage to PGR treatments when grown in 4-inch and 1-gallon pots in a greenhouse, and when grown in 1-gallon pots under outdoor nursery conditions.

METHODS

Greenhouse: 4-inch pots. Rooted cuttings were transplanted on February 3, 1999, to 4-inch square pots containing a peat-based medium and placed in a double-poly greenhouse. PGR treatments, applied as foliar sprays on February 26, included Cutless at 50, 100, or 150 ppm; Sumagic at 20, 40, or 60 ppm; B-Nine/Cycocel tank mixes at 2,500/1,500, 5,000/1,500, or 7,500/1,500 ppm; Pistill at 500 or 1000 ppm, and a non-treated control. Growth index [GI = (height + widest width + width perpendicular to first width)÷3] was determined at 2-week intervals, starting at 2 weeks after treatment (WAT), and continued until treatment effects were no longer significant. At 6 WAT, half of the plants in each treatment were randomly selected and planted in outdoor ground beds to determine the persistence of PGR treatments in a landscape setting.

Greenhouse and nursery: 1-gallon pots. Methodology was identical for the greenhouse and nursery portion with 1-gallon pots unless otherwise indicated. Dormant Russian sage were transplanted in March 1999 from 6-inch pots to 1-gallon pots containing an amended pinebark: sand medium. Plants were placed either in a heated greenhouse or outdoors in a nursery.

On May 7, Russian sage were pruned at 8 inches above the pot rims, and treatments were applied when regrowth was about 1 inch in length. The same PGR treatments used on Russian sage in 4-inch pots were applied to plants in 1-gallon pots on May 18. Plants were not transplanted into the landscape.

RESULTS

Greenhouse: 4-inch pots. Growth of Russian sage in the greenhouse pots was reduced by all PGRs through 6 WAT (Table 1). Plants treated with the three rates of Cutless were 7%, 15 to 20%, and 12 to 28% smaller than controls at 2, 4, and 6 WAT, respectively. At 8 WAT, these plants were still 14 to 32% smaller than control plants after growing in the landscape for 2 weeks. Plants treated with Sumagic were 13%, 30%, and 32 to 36% smaller than control plants at 2, 4, and 6 WAT, respectively. Sumagic-treated plants were 32% smaller than controls at 8 WAT; however, by 10 WAT, size differences were non-significant in the landscape. For plants treated with B-Nine/Cycocel tank mixes, shoot growth was suppressed 7%, 15 to 20%, and 20% at 2, 4, and 6 WAT, with GI of treated plants still 14 to 25% less than that of control plants at 8 WAT. In the landscape, all plants recovered rapidly from PGR treatment effects (Table 1). The rate of growth for non-treated controls did not change much after they were transplanted into the ground; plants grew 2.8 inches between 6 and 10 WAT. However, PGR-treated plants grew 2.4 to 4.7 inches over the same time period. Application of Cutless, Sumagic, or B-Nine/Cycocel tank mixes did not affect the overall appearance of plants (excluding size); leaves and flowers were similar to those on non-treated plants and no phytotoxicity was observed.

Pistill-treated plants were 7 to 13%, 20 to 30%, and 28 to 36% smaller than control plants at 2, 4, and 6 WAT, respectively. At 8 WAT, these plants were 32% smaller than control plants, and flowers were present on only 40% of Pistill-treated plants while all control plants were flowering. Flowering delay is a common side effect with Pistill application.

Greenhouse: 1-gallon pots. For plants treated with Cutless, effects on growth were not apparent until 4 WAT (Table 2). After that time, growth was retarded 7 to 22%, 9 to 25%, and 6 to 21% at 4, 6, and 8 WAT, respectively. Sumagic-treated plants were 0 to 17%, 16 to 23%, 12 to 23%, and 11 to 22% smaller than control plants at 2, 4, 6, and 8 WAT, respectively. Growth of plants treated with B-Nine/Cycocel tank mixes was suppressed 17 to 24%, 25 to 33%, 21 to 27%, and 16 to 22%, while application of Pistill resulted in reductions in GI of 17 to 24%, 32 to 36%, 22 to 27%, and 12 to 16% at 2, 4, 6, and 8 WAT, respectively. At 2 and 4 WAT, B-Nine/Cycocel tank mixes and Pistill provided more control of growth than Cutless or Sumagic, and at 6 WAT, they were more effective than Cutless (Table 2). At 8 WAT, growth suppression was similar among PGRs. At 10 and 12 WAT, GI was reduced by all PGRs except Pistill; however, plants exhibited shoot die-back and decreased vigor, probably due to increased heat, and being pot-bound, so data are not presented or further discussed.

Table 1. Growth Index[1] of Russian Sage Grown in 4-inch Pots Following Treatment with Several Plant Growth Retardants in the Greenhouse and after Transplanting Outdoors into Ground Beds

Growth retardant	Rate (ppm)	Greenhouse 2WAT[2]	4 WAT	6 WAT	Landscape 8 WAT[2]	10 WAT
Control	0	15	20	25	28	32
Cutless	50	14	17	22	23	28
	100	14	16	20	24	31
	150	14	16	18	19	27
Sumagic	20	13	14	17	19	25
	40	13	14	17	19	29
	60	13	14	16	19	26
B-Nine/	2,500/1,500	14	17	20	22	29
Cycocel	5,000/1,500	14	16	20	21	29
	7,500/1,500	14	16	20	24	30
Pistill	500	14	16	18	19	28
	1,000	13	14	16	19	26

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment; Russian sage were transplanted into ground beds at 6 WAT.

Nursery. Growth control provided by Cutless was inconsistent in the nursery throughout the experiment (Table 3). At 2 WAT, Cutless-treated plants were 5 to 11% smaller than controls, but Cutless treatments were non-significant at 4 and 8 WAT. For Sumagic-treated plants, growth was suppressed 7 to 14% at 2 WAT. At 4 WAT, increased rates of Sumagic resulted in a decrease in GI; however, the greatest control was only 7%. Under nursery conditions, growth control with one application of either Cutless or Sumagic at the rates tested had little practical benefit. Control of GI with Cutless or Sumagic in the nursery appeared to be of shorter duration and lower magnitude than in the greenhouse with plants in 4-inch or 1-gallon pots.

B-Nine/Cycocel tank mixes and Pistill were more effective than Cutless or Sumagic at 4, 6, and 8 WAT (Table 3). Control with these chemicals appeared to be less than that obtained under greenhouse conditions. Plants treated with B-Nine/Cycocel tank mixes were 7 to 16%, 14 to 17%, 10 to 16%, and 9 to 13% smaller than non-treated plants at 2, 4, 6, and 8 WAT, respectively, but similar at 10 WAT. Under greenhouse conditions, the range of control of plants in 1-gallon pots with B-Nine/Cycocel tank mixes was 17 to 33% through 8 WAT. Plants treated with B-Nine/Cycocel tank mixes and grown in 4-inch pots were 14 to 21% smaller than control plants after growing in ground beds for 2 weeks (8 WAT). Growth of Pistill-treated plants outdoors was retarded 18 to 25%, 17 to 26%, 13 to 27%, and 4 to 10% at 2, 4, 6, and 8 WAT, respectively, as compared to control plants, but the effects were non-significant at 10 WAT.

Table 2. Growth Index[1] of Russian Sage Grown in 1-gallon Pots Following Treatment with Several Plant Growth Retardants under Greenhouse Conditions

Growth retardant	Rate (ppm)	Growth Index 2WAT[2]	4 WAT	6 WAT	8 WAT
Control	0	41	73	81	85
Cutless	50	40	67	73	80
	100	38	68	74	74
	150	41	57	61	67
Sumagic	20	41	61	65	71
	40	35	61	71	76
	60	34	56	62	66
B-Nine/	2,500/1,500	32	55	64	71
Cycocel	5,000/1,500	31	49	59	65
	7,500/1,500	34	50	59	66
Pistill	500	34	50	59	71
	1,000	31	47	63	75

[1] Growth index = (height + widest width + width perpendicular) ÷ 3, in cm.
[2] WAT = Weeks after treatment.

In conclusion, for all PGRs applied, growth suppression appeared to be less under nursery conditions compared to greenhouse conditions. However, both B-Nine/Cycocel tank mixes and Pistill provided more effective size control under nursery conditions than Cutless or Sumagic. B-Nine/Cycocel tank mixes may be a better choice for size control under nursery conditions because results obtained in the greenhouse portion of this test with 4-inch pots suggest delayed flowering with Pistill.

Table 3. Growth Index[1] of Russian Sage Grown in 1-Gallon Pots Following Treatment with Several Plant Growth Retardants in a Nursery

Growth retardant	Rate (ppm)	Growth index 2WAT[2]	4 WAT	6 WAT	8 WAT	10 WAT
Control	0	44	58	70	78	75
Cutless	50	42	60	77	81	•[3]
	100	39	55	73	79	•
	150	39	56	67	82	•
Sumagic	20	41	58	77	83	•
	40	39	55	69	75	•
	60	38	54	73	79	•
B-Nine/ Cycocel	500/1,500	41	50	63	70	70
	5,000/1,500	38	49	63	71	71
	7,500/1,500	37	48	59	68	72
Pistill	500	36	48	61	75	77
	1,000	33	43	51	70	80

[1] Growth index = (height + widest width + width perpendicular)÷3, in cm.
[2] WAT = Weeks after treatment.
[3] • = Data were not collected for Cutless or Sumagic-treated plants due to lack of significance at 8 WAT.

Growth control from Cutless and Sumagic in the greenhouse, even when applied to large plants grown in 1-gallon pots, appeared to be more effective and of greater persistence than under nursery conditions. A possible factor contributing to decreased PGR effectiveness in the nursery is plants in the nursery are watered more frequently and with higher volumes than applied in the greenhouse, resulting in increased plant growth. While B-Nine/Cycocel tank mixes provided significant growth control for 8 weeks under nursery conditions, plant appearance would have been improved if size control had been greater; this would probably require higher rates or multiple applications.

Response of 'Foxy' Foxglove to GA_3 and Cold Treatment

Gary J. Keever

Foxgloves are known for their stately spikes of color in shades of purple, pink, or white. Being true biennials or weak perennials, foxgloves rosette the first season from seed and bloom the next spring. For spring flowering plants, foxglove seed can be sown the previous year until November and grown cold, but not dormant, during the winter. Flowering is often sporadic during late spring and early summer. However, foxgloves often live through one more winter and flower more profusely the following spring.

One variety, 'Foxy', will flower as an annual if started early enough from seed. Production guides for 'Foxy' suggest sowing seed in December or January for flowering plants in May and June. This, however, is past the peak period of spring marketability in the southeastern United States, and non-uniform flowering in 'Foxy' may further reduce its sales. While earlier sowing may address the late flowering problem, other cultural practices may shorten cropping time and improve uniformity of flowering.

Gibberellins (GA), including GA_3 and GA_{4+7}, have been used to accelerate flowering and enhance uniformity of flowering in numerous horticultural crops. An alternative is to subject plants to a period of low temperature prior to forcing them into flower. Cold treatment, or vernalization, is required for biennials to flower, and many herbaceous perennials not requiring vernalization flower earlier and more uniformly when exposed to cold treatment. The objective of this research was to determine the effects of GA_3 application and cold treatment on flowering in 'Foxy' foxglove. The overall goal was to accelerate flowering and enhance uniformity of flowering without reducing plant quality.

METHODS

Experiment 1. Uniform, seed-grown liners of 'Foxy' foxglove were transplanted from 36-cell packs into 5-inch pots containing a commerical peat-based medium. Containers were placed in an unshaded double-layer polyethylene greenhouse and liquid fed. Five weeks after transplanting single foliar sprays of 0, 10, 25, 50, 100, 125, 250, 500, 750, or 1,000 ppm GA_3 were applied. At the time of the first opened flower, date, height, foliar color rating (1, 3, and 5 = light, medium, and dark green, respectively), and the number of inflorescences were recorded.

Experiment 2. Methodology in the second experiment was the same as that in the first experiment unless stated otherwise. One hundred and twenty uniform liners of 'Foxy' foxglove were transplanted into 1-gallon pots. Three low temperature durations (0, 2, or 4 weeks) were evaluated by placing 80 plants each in a dark cooler at 40°F; 40 plants remained in the greenhouse. Cooled plants were returned to the greenhouse and on the following day, single foliar sprays of 0, 16.7, 33.3, or 50 ppm GA_3 were applied to 10 plants from each of the three low temperature group.

RESULTS

Experiment 1. Days to the first open flower (DTF) was not significantly affected by treatments although there was a trend for earlier flowering with GA_3 treatment (control = 61 DTF, treated = 53 DTF). Flowering occurred in 30% of controls, 70% of plants treated with 10 ppm GA_3, and 100% of all other treatments (Table 1). Heights were similar for controls and plants treated with 50 ppm GA_3, and inflorescence lengths were considered proportional to plant and pot sizes. The height of plants treated with 75 ppm GA_3 averaged 74% more than that of the controls. Inflorescences of plants treated with these higher rates of GA_3 were excessively elongated relative to plant and pot sizes. Flowers on plants treated with 100 ppm GA_3 were malformed or incompletely developed, while flowers on plants treated with rates greater than 100 ppm GA_3 appeared to have fewer flowers per inflorescence, and flowers appeared to senesce earlier. Foliar color rating decreased with increasing GA_3 rate although ratings for plants treated with 100 ppm or less of GA_3 were numerically similar.

Table 1. Response of Foxglove to Gibberellic Acid (GA_3) (Experiment 1)

GA_3 rate (ppm)	Flowering (%)	Height (cm)
Control	30	28.7
10	70	31.4
25	100	32.3
50	100	35.8
75	100	50.9
100	100	48.8
125	100	48.4
250	100	51.8
500	100	48.1
750	100	52.7
1,000	100	49.0

Table 2. Response of Foxglove to Gibberellic Acid (GA_3) (Experiment 2)

GA_3 rate (ppm)	Days to flower	Flowers per inflorescence	Height (cm)
Control	95	15.4	60.9
16.7	66	24.3	77.6
33.3	62	25.1	92.6
50.0	67	24.2	82.2

Overall, GA_3 rates of 10 to 50 ppm promoted flowering (70 to 100%) compared to 30% for the untreated control. These plants were compact with attractive foliage and considered highly marketable. Although foxglove treated with rates of GA_3 greater than 50 ppm flowered, many of the flowers were malformed or incompletely developed and inflorescences were excessively elongated. Also, leaves appeared thinner, strap-like, and noticeably lighter green in color.

Experiment 2. DTF was affected by GA_3 and cold treatment. GA_3-treated plants flowered an average of 30 days earlier than controls (Table 2). Cooling plants for 4 weeks prior to forcing also accelerated flowering: 67 DTF vs. 75 and 73 DTF for 0 and 2 weeks of cold, respectively. Flowering in GA_3 controls cooled for 0 and 2 weeks was 90% and 60%, respectively, and 80% in non-cooled plants treated with 16.7 ppm GA_3, while 100% of plants in all other treatments flowered.

GA_3-treated plants were an average of 38% taller than controls. Height in response to GA_3 rate increased up to 33.3 ppm before declining at 50 ppm. Quality rating was higher for control plants than for plants treated with GA_3, primarily due to more elongation of the inflorescence in GA_3-treated plants. This trend is reflected in height data. Although GA-treated plants were taller and the quality rating lower, heights of these plants were proportional to plant width and pot size and plants were considered marketable.

Based on results of these two experiments, application of 10 to 50 ppm GA_3 offers potential benefits in the production of 'Foxy' foxglove. Plants treated with GA_3 in this range flowered earlier, more uniformly, and with higher flower counts per inflorescence, which translates into less bench time. These plants had attractive foliage and were considered marketable. All foxglove treated with higher rates of GA_3 flowered but many of the flowers were malformed, inflorescences were excessively elongated, and leaves were thinner, strap-like, and noticeably lighter green. Cooling plants at 40°F for 4 weeks shortened the number of days to flower, and in the absence of GA_3 increased the number of inflorescence compared to plants not cooled.

Growth Regulation of *Canna* × *generalis* 'Florence Vaughan'

Laura L. Bruner, Gary J. Keever, J. Raymond Kessler, and Charles H. Gilliam

Canna × *generalis* 'Florence Vaughan' or canna lily is a herbaceous perennial, growing 45 inches tall and producing gladiolus-like flowers from mid-summer through late fall. Flowers are sulphur yellow, with a large nasturtium-orange blotch fading into spots. Flowers are held on peduncles, which typically extend around 4 inches above the foliage when in bloom. The leaves are bright, apple green, elliptical, and originate sheath-like from the petiole. Canna lilies exhibit rapid growth and a top-heavy growth habit resulting from the upright position of the leaves. Canna lilies are often difficult to manage when grown in one-gallon containers due to these characteristics. Common problems include frequent blow-over during production and later at retail facilities, and increased shipping costs, especially when plants are racked during shipment.

Plant growth retardants (PGRs), including B-Nine, Pistill, Bonzi, and Cutless, are effective in suppressing height in numerous plant species and may offer benefits in the production, shipping, and marketing of canna lilies. B-Nine, Bonzi, and Pistill are labeled for use on herbaceous crops in greenhouses and nurseries, while Cutless is labeled for use on turfgrass only. While these PGRs have been effective on numerous horticultural crops, none are specifically labeled for use on canna lily during nursery production. PGRs used in production occasionally have residual effects that carry over into the landscape. One potential residual effect, suppressed growth in the landscape, may reduce the intended visual effect of plants, as well as customer satisfaction. The objective of this study was to determine the effects of several rates of four PGRs on the height and flowering of canna lily during container production and landscape establishment.

METHODS

This study was conducted twice, in the spring of 1998 and 1999. Dormant 'Florence Vaughan' canna lilies in 1-gallon containers were divided into quarters and repotted into 1-gallon containers containing an amended pine bark:sand medium. Plants were grown outdoors in full sun under twice daily overhead irrigation. Prior to PGR application, initial height measurements were taken. Average initial heights ranged from 15.6 inches to 17.0 inches and 18.4 inches to 21.2 inches in 1998 and 1999, respectively. PGR treatments, applied as foliar sprays, included B-Nine at 2500, 5000, and 7500 parts per million (ppm); Bonzi at 33, 66, and 99 ppm; Cutless at 50, 100, and 150 ppm; and Pistill at 125, 250, 500, 750, and 1000 ppm; and an untreated control (water). Treated plants were returned to the nursery container area on the following day.

Plant height, from the substrate surface to the tallest vegetative point (uppermost leaf), was measured at 30 and 60 days after treatment (DAT) and at first flower. Plants were observed daily for flowering, and days to flower (DTF) and flowering height measured at first flower were recorded daily. DTF was defined as the number of days from PGR application until the first fully opened bloom. Flowering height was measured from the substrate surface to the top of the inflorescence of the first fully opened flower.

Following data collection at 60 DAT, treatments that exhibited PGR effects at 30 or 60 DAT were transplanted into the landscape to assess residual PGR effects. Height measurements were collected at 30, 60, and 90 days after planting (DAP) in the landscape. In 1998 plants treated with Bonzi and Cutless and untreated controls were transplanted into the landscape. In 1999 Cutless treated plants and untreated controls were transplanted into the landscape. Landscape beds were located in full sun and irrigated as needed.

RESULTS

Of the four PGRs studied, only Cutless consistently suppressed vegetative and flowering heights during container production in both 1998 and 1999 (Tables 1 and 2). At first flower, Cutless suppressed flowering height 50 to 68% in 1998 and 50 to 75% in 1999. Vegetative height at first flower was suppressed by Cutless 39 to 50% in 1998 and 30 to 35% in 1999. Average flowering height of Cutless-treated plants was less than that of the foliage. This suppression was least pronounced at the lowest rate, with foliage on average 2 inches taller than the inflorescence in both experiments. Suppression of flowering heights compared to foliage heights at the higher Cutless rates was similar with foliage around 2.5 inches taller than the inflorescence in 1998, but significantly more pronounced in 1999 with foliage between 8.7 inches and 13.0 inches taller than inflorescence. For canna lilies, the flowering height reduction detracted from the floral display of treated plants which would be detrimental to plant marketability. Following transplanting, flowering heights among treated and untreated plants appeared similar by 30 DAP.

The observed effects on time to flower are not likely to be a major detriment or benefit to commercial growers, especially if the effects are unpredictable.

At 30 DAT, Cutless suppressed vegetative height 42 to 50% in 1998 and 18 to 21% in 1999. At 30 DAT, the lowest rate of Cutless suppressed canna lily height more than the highest rate of Bonzi in either year. At 60 DAT, vegetative height of Cutless-treated plants was suppressed 37 to 47% and 21 to 39% compared to untreated plants in 1998 and 1999, respectively.

Cutless-treated and untreated plants were transplanted into the landscape both years to assess residual effects of PGRs in the landscape. At 30 DAP, height was suppressed by Cutless, 5 to 14% in 1998 and 14 to 23% in 1999. The difference in height between plants treated at the lowest rate of Cutless and untreated plants was small, only 5% (1998) and 14% (1999); this difference would hardly be distinguishable to the consumer. Cutless treatment effects on vegetative height dissipated between 30 and 60 DAP.

B-Nine and Pistill did not exhibit effective, consistent height suppression in the 1998 or 1999 experiment. Based on these results neither PGR at the rates tested appears useful in controlling canna lily height. Bonzi provided growth suppression for a limited time in 1998, but not at all in 1999.

In summary, Cutless was effective and consistent in controlling height of canna lily. However, marketability of Cutless-treated plants may be reduced based on the excessive retardation of flowering height at initial flowering and residual height suppression in the landscape observed with 100 and 150 ppm. Relatively little vegetative height difference occurred between the lowest and highest rates, suggesting little justification for exceeding an application rate of 50 ppm. The reduction in plant size at the lowest rate tested should facilitate shipping and handling and reduce maintenance activities during production.

However, due to excessive suppression of flowering height at first flower and residual vegetative height suppression persisting into the landscape, rates of Cutless tested may be considered excessive for canna lily. B-Nine, Pistill, and Bonzi at the rates tested were inconsistent or ineffective in controlling vegetative height of canna lily during nursery production.

Table 1. Vegetative and Inflorescence Heights and Days to Flower for *Canna ×generalis* 'Florence Vaughan' Treated with B-Nine, Pistill, Bonsi, or Cutless (1998)

		First flower			Vegetative height (inches)				
					Container production		Landscape		
Growth retardant	Rate (ppm)	Days to flower	Vegetative height (in)	Inflorescence height (in)	30 DAT[1]	60 DAT	30 DAP[2]	60 DAP	90 DAP
Control	0	42	33.8	36.6	33.7	34.0	37.2	40.6	43.4
B-Nine	2500	40	34.2	39.3	34.0	38.2	—[3]	—	—
	5000	45	36.7	36.2	34.6	38.7	—	—	—
	7500	50	35.2	38.7	35.2	37.6	—	—	—
Pistill	125	42	34.1	33.7	32.1	36.4	—	—	—
	250	42	33.8	36.0	32.7	35.9	—	—	—
	500	45	35.2	33.8	35.2	36.9	—	—	—
	750	42	33.4	34.1	32.8	37.7	—	—	—
	1000	42	32.7	34.4	32.6	36.8	—	—	—
Bonzi	33	43	30.1	37.0	28.6	36.4	39.1	40.8	44.5
	66	46	30.7	36.3	26.8	35.6	36.9	43.9	46.1
	99	43	25.4	29.4	24.2	32.8	38.6	43.3	48.9
Cutless	50	41	20.8	18.6	19.7	21.7	35.5	42.8	43.2
	100	43	19.3	17.2	18.1	19.3	30.9	40.8	42.6
	150	48	17.2	11.9	17.1	18.1	31.9	38.9	42.8

[1] DAT = Days after treatment. [2] DAP = Days after planting into landscape. [3]Treatment not included in experiment at indicated data collection.

Table 2. Vegetative and Inflorescence Heights and Days to Flower for *Canna ×generalis* 'Florence Vaughan' Treated with B-Nine, Pistill, Bonsi, or Cutless (1999)

		First flower			Vegetative height (inches)				
					Container production		Landscape		
Growth retardant	Rate (ppm)	Days to flower	Vegetative height (in)	Inflorescence height (in)	30 DAT[1]	60 DAT	30 DAP[2]	60 DAP	90 DAP
Control	0	47	32.3	41.4	26.8	35.9	41.0	43.7	45.2
B-Nine	2500	46	34.3	44.6	28.2	38.0	—[3]	—	—
	5000	41	32.7	39.2	28.4	37.4	—	—	—
	7500	45	34.5	43.5	28.8	36.3	—	—	—
Pistill	125	42	27.4	35.1	25.1	33.6	—	—	—
	250	40	29.0	36.0	25.9	34.2	—	—	—
	500	45	28.8	36.4	24.5	35.3	—	—	—
	750	52	32.7	39.9	23.7	36.0	—	—	—
	1000	48	27.9	33.8	22.4	32.5	—	—	—
Bonzi	33	45	31.3	41.8	26.8	35.1	—	—	—
	66	43	29.0	37.0	24.7	32.9	—	—	—
	99	47	30.4	40.0	25.9	34.6	—	—	—
Cutless	50	42	22.9	21.0	22.3	25.1	35.7	43.9	45.2
	100	46	21.4	12.8	21.6	22.3	32.8	39.5	42.6
	150	36	23.7	10.8	21.4	23.1	32.0	41.6	43.3

[1] DAT = Days after treatment. [2] DAP = Days after planting into landscape. [3]Treatment not included in experiment at indicated data collection.

Growth Retardant Application to 'Florence Vaughan' Canna Lily

Laura L. Bruner, Gary J. Keever, J. Raymond Kessler, and Charles H. Gilliam

The tall, upright foliage and continuous flowering of *Canna × generalis* 'Florence Vaughan' or canna lily make this traditional, herbaceous perennial popular with consumers. Sulphur-yellow flowers with an orange blotch typically extend 4 inches above the foliage when in bloom, mid-summer through fall. The plant's tall, upright nature and rapid growth make it difficult to manage during production and at retail facilities due to frequent blow-over when grown in three-gallon or smaller containers. Additionally, taller plants increase shipping costs, especially when plants are racked for shipment. Plant growth retardants (PGRs) are effective in suppressing the height of numerous crops and may benefit production of canna lily. Previous research with Cutless, a plant growth retardant labeled for turfgrasses, has shown it effective on canna lilies. However, Cutless at rates of 50 ppm or greater reduced the overall floral display.

Bonzi and B-Nine are effective in height suppression of numerous plant species but were not consistently effective in suppressing canna lily height in a previous study. Sumagic is similar in chemical form to Bonzi but more effective in height suppression of many crops. Additionally, in previous research, B-Nine/Cycocel combinations were more effective in controlling plant height than either PGR alone. Cutless at rates lower than 50 ppm, Sumagic, or B-Nine/Cycocel tank mixes may offer benefits in the production, shipping, and marketing of canna lilies.

Postproduction PGR effects are a concern to both growers and consumers. Once plants reach marketable size or stage they may be held in containers for an extended period until sold in the retail market. Continued height suppression of plants remaining in containers would reduce maintenance in the wholesale and retail settings. However, continued height suppression may be a disadvantage once plants are transplanted into the landscape, reducing customer satisfaction. The objective of this study was to determine the effects of several rates of four PGRs on the height and flowering of canna lily during container production and subsequent landscape establishment.

METHODS

In spring 2000, dormant 'Florence Vaughan' canna lilies in one-gallon containers were quartered and repotted into three-gallon containers containing an amended pine bark:sand medium. Plants were grown outdoors in full sun under twice daily overhead irrigation. PGRs were applied foliarly and included B-Nine/Cycocel tank mixes at 2500/1500, 5000/1500, and 7500/1500 parts per million (ppm); Cutless at 15, 30, and 45 ppm; Sumagic at 20, 40, and 60 ppm; and an untreated control. Plant vegetative height was measured at 14, 30, and 60 days after treatment (DAT) and at first and second flower. Days to flower of the first and second inflorescence (DTFF and DTSF) were recorded; flowering heights and peduncle lengths were measured at first and second flower. DTFF and DTSF were defined as the number of days from PGR application until the first fully opened bloom on the first and second inflorescence, respectively.

Following data collection at 60 DAT (July 15, 2000), six plants from each treatment were transplanted into the landscape with the remaining four left in containers to assess residual PGR effects. Thereafter, only vegetative heights of containerized and landscape plants were recorded at 90, 120, and 150 DAT. Landscape beds were located in full sun and irrigated as needed.

RESULTS

Cutless suppressed vegetative height 1 to 11% (14 DAT) and 13 to 27% (30 DAT) (Table 1). There was no delay in flowering of either the first or second inflorescence in Cutless-treated plants (Table 2). Vegetative height was suppressed by Cutless at first and second flower with treated plants 20 to 39% and 21 to 33% shorter than controls, respectively. At first flower, flowering heights were suppressed 18 to 55% by Cutless, with a suppression of 23 to 43% at second flower. At first flower, flowering height

Table 1. Vegetative Heights of 'Florence Vaughan' Canna Lily During Container Production Following Treatment with Cutless, B-Nine/Cycocel, or Sumagic

		—Vegetative height (in)—		
	Rate (ppm)	14 DAT[1]	30 DAT	60 DAT
Control		20.8	26.8	39.0
Cutless	15	20.6	23.5	31.9
	30	18.9	19.5	26.8
	45	18.6	19.6	23.7
B-Nine / Cycocel	2500/1500	20.8	23.4	28.5
	5000/1500	20.7	25.8	33.3
	7500/1500	20.8	25.0	32.2
Sumagic	20	18.0	18.2	19.2
	40	18.1	18.3	19.1
	60	19.4	19.5	19.8

[1] DAT = Days after treatment.

Table 2. Vegetative and Flowering Heights at First and Second Flower for *Canna* × *Generalis* 'Florence Vaughan' Treated with Cutless, B-Nine/Cycocel, or Sumagic

	Rate (ppm)	First flower Days to flower	Vegetative height (in)	Flowering height (in)	Peduncle length (in)	Second flower Days to flower	Vegetative height (in)	Flowering height (in)	Peduncle length (in)
Control	0	49	35.7	41.0	11.7	57	38.8	45.5	13.6
Cutless	15	50	28.7	33.9	11.7	58	30.8	35.1	13.4
	30	51	23.1	26.8	11.2	60	26.1	26.2	10.5
	45	51	21.8	18.2	5.8	57	26.2	26.1	9.3
B-Nine/ Cycocel	2500/1500	49	25.5	29.5	10.2	62	25.4	27.0	9.7
	5000/1500	49	32.5	38.7	13.7	57	34.0	40.5	12.2
	7500/1500	51	30.8	34.4	11.5	61	33.3	38.3	14.4
Sumagic	20	51	17.4	11.4	1.8	62	17.5	12.0	2.2
	40	51	17.9	10.3	2.0	64	17.5	11.7	2.2
	60	51	18.8	10.9	1.8	61	18.7	17.4	4.6

suppression of plants treated with 15 or 30 ppm Cutless was proportional to foliage, with both foliage and flowering heights between 17 and 20% (15 ppm) and around 36% (30 ppm) shorter than those of control plants. At these rates, inflorescences extended about 15 inches above the foliage, and peduncle lengths were essentially the same as those of control plants. At second flower, inflorescences extended 4.3 inches above foliage for plants treated with 15 ppm Cutless, but were suppressed to a height equal to foliage with 30 and 45 ppm Cutless. Peduncle lengths for the second flowering event were suppressed with similar lengths at the lowest rate to 33% shorter compared to those of control plants. No obvious differences in leaf orientation were observed at the 15 or 30 ppm rates compared to control plants. However, leaves of plants treated with 45 ppm Cutless appeared less upright during container production and similar in appearance to canna lilies in a previous study that were excessively suppressed.

At 60 DAT, vegetative height of Cutless-treated plants was suppressed 18 to 40% compared to control plants. At 90 DAT (Table 3), plants in containers and those transplanted into the landscape were similar in height. Plants in the landscape were around 3 inches and 3.5 inches taller than those in containers at 120 and 150 DAT, respectively. However in both locations, height was suppressed by Cutless, 15 to 32% at 90 DAT and 7 to 12% at 120 DAT, respectively, compared to control plants. At the lowest rate of 15 ppm, this suppression was 6 inches at 90 DAT and 2.5 inches at 120 DAT, which would not likely be discernable by consumers. Height suppression from Cutless treatments dissipated completely by 150 DAT. During the dissipation of treatment effects, plants treated with all rates of Cutless grew more rapidly than control plants throughout the remainder of the study. The difference was most dramatic between 90 and 120 DAT with changes in height of 6.3 inches at 15 ppm, 8.4 inches at 30 ppm, and 11.8 inches at 45 ppm compared to 3.3 inches for control plants.

Vegetative height was suppressed during container production by B-Nine/Cycocel and was first evidenced at 30 DAT, with treated plants 5 to 14% (30 DAT), 9 to 14% (first flower), 16 to 28% (60 DAT), and 13 to 35% (second flower) shorter than control plants. There was no delay in time to first or second flower. First flower occurred about 50 DAT, with second flower occurring about 58 DAT. At first and second flower, flowering heights of treated plants extended above foliage 3.5 to 6.3 inches and 1.5 to 6.7 inches, respectively, compared to 5.5 and 6.6 inches for control plants. At 90 and 120 DAT, height was suppressed in containers, up to 33% (90 DAT) and 17% (120 DAT), and in the landscape, 14 to 23% (90 DAT) and 6 to 16% (120 DAT). Location (container vs. landscape) affected only plants treated with the lowest rate of B-Nine/Cycocel; containerized plants were 21% and 16% shorter than those in the landscape at 90 and 120 DAT, respectively. This implies that growth suppression with the lowest rate of B-Nine/Cycocel dissipated quicker in plants transplanted into the landscape than in those maintained in containers. By 150 DAT, plants were no longer affected by B-Nine/Cycocel rate at either location, with transplanted plants slightly taller (4 inches) than containerized plants.

The range of plant heights observed within each B-Nine/Cycocel treatment was much greater than those within control, Cutless, or Sumagic treatments. The large range of variation within each of the B-Nine/Cycocel treatments suggests inconsistent height suppression and would result in an unpredictable, non-uniform crop.

Sumagic provided consistent, significant height suppression throughout container production; however, elongation of inflorescences was severely suppressed and leaf orientation altered. Vegetative height of treated plants was 6 to 14% (14 DAT) and 28 to 33% (30 DAT) shorter than control plants. There was no delay in flowering of the first inflorescence, but a 3- to 7-day delay in flowering of the second. Flowering height and peduncle length were suppressed by Sumagic at first and second flower. At first

Table 3. Vegetative Heights (Inches) of 'Florence Vaughan' Canna Lily Treated with Cutless, B-Nine/Cycocel, or Sumagic 90 Through 150 Days after Treatment

	Rate(ppm)	90 DAT[2]		120 DAT		150 DAT	
		Container or Landscape[1]					
		Across location					
	Control	40.2		43.5		46.9	
Cutless	15	34.4		40.7		45.2	
	30	30.0		38.4		44.1	
	45	27.4		39.2		45.5	
		Across Cutless rate					
		Container	Landscape	Container	Landscape	Container	Landscape
		78.9	77.1	98.8	105.5	107.5	118.8
		Container	Landscape	Container	Landscape	Landscape and Container Combined	
	Control	37.7	41.8	40.9	45.1	46.9	
B-Nine / Cycocel	2500 / 1500	25.5	32.5	34.3	40.7	42.5	
	5000 / 1500	34.3	36.3	38.7	42.7	44.0	
	7500 / 1500	37.9	32.5	41.7	38.0	44.4	
		Across B-Nine/Cycocel rate					
						Container	Landscape
						41.1	45.2
		Across location				Container	Landscape
	Control	40.2		43.5		43.2	49.4
Sumagic	20	20.5		31.4		29.7	44.1
	40	21.0		29.9		24.8	44.2
	60	22.3		31.1		28.5	42.6
		Across Sumagic rate					
		Container	Landscape	Container	Landscape	Container	Landscape
		24.4	27.8	23.4	36.3	31.5	45.1

[1] Six of ten plants were transplanted into landscape at 60 DAT (July 15, 2000).
[2] DAT = Days after treatment.

and second flower, flowerings were 6 to 8 inches and 1.2 to 6 inches below foliage, respectively. Peduncle lengths were suppressed 85% at first flower and 65 to 83% at second flower. Flowering height retardation was considered excessive and detracted from the floral display, which would likely reduce marketability. Vegetative heights at first and second flower were suppressed by Sumagic from 47 to 52% (first flower) and 56% (second flower) compared to controls. Vegetative height at 60 DAT was suppressed by Sumagic with treated plants 50 to 52% shorter than control plants. At all Sumagic rates, leaf orientation appeared altered due to restriction of internode elongation. The excessive flowering height retardation and altered leaf orientation were similar to effects from 100 and 150 ppm Cutless in a previous study with canna lilies. The overall plant form, at these rates of Sumagic and with higher rates of Cutless, was uncharacteristic of canna lily and would likely be detrimental to marketability.

At 90 and 120 DAT, plants remaining in containers were around 3 inches shorter at 90 DAT and 13 inches shorter at 120 DAT than those in the landscape, regardless of Sumagic rate. Sumagic suppressed vegetative height 45 to 49% (90 DAT) and 29 to 31% (120 DAT) compared to controls in both locations. At 150 DAT, there was greater height suppression for Sumagic treated plants in containers compared to plants transplanted into the landscape. Vegetative height of treated plants remaining in containers was suppressed 32 to 43% compared to a suppression of 11 to 14% with increasing PGR rate in transplanted plants. Evidence of canna lilies outgrowing treatment effects was seen in new shoots that eventually increased in height above that of treated foliage. Plants remaining in containers were significantly pot-bound by 60 DAT, demonstrated by the visible distortion of their plastic pots from rhizomes and roots. New shoot production following transplanting into the landscape at 60 DAT appeared much greater than that of plants remaining in containers, resulting in taller plants exhibiting less overall suppression.

In summary, Cutless applied at 15 or 30 ppm was effective in controlling height of canna lily without any detriment to the overall floral display. Excessive flowering height retardation and altered plant form observed with 45 ppm Cutless make this rate unacceptable for use on plants marketed in the season of application. Residual effects from Cutless were not influenced by plant location, and at 15 ppm treated plants were only 7% shorter than controls at 120 DAT with no suppression effects at 150 DAT.

At the rates tested, B-Nine/Cycocel provided height suppression without excessive flowering height retardation or altered leaf orientation. However, large variations in height suppression were observed within B-Nine/ Cycocel treatments and response was inconsistent with rate. Therefore, height suppression from B-Nine/Cycocel may be less predictable than with Cutless and possibly result in a non-uniform crop.

Sumagic exhibited effective, but excessive height suppression during container production. Based on the excessive retardation of flowering height at all rates tested and altered plant form, plant marketability may be reduced, even at the lowest rate. Sumagic at rates below 20 ppm could provide height control without excessive retardation and suppression and may warrant further study.

Growth Retardant and Initial Plant Height Affect Canna Lily Growth and Flowering

Laura L. Bruner, Gary J. Keever, J. Raymond Kessler, and Charles H. Gilliam

Canna lilies often emerge from dormancy or from new divisions in spring at non-uniform rates. Rapid growth following emergence and upright foliage 45 inches tall make *Canna ×generalis* 'Florence Vaughan' canna lily a potential candidate for growth regulation using plant growth retardants (PGRs) during container production. With non-uniform emergence typical in canna lilies, crop height at the time of PGR application may also be non-uniform. One factor influencing PGR efficacy is the stage of plant development or plant height at the time of PGR application, with larger or more advanced plants of many species being less responsive.

PGRs are effective in suppressing height in numerous species. Cutless, a PGR labeled for turfgrasses, has been effective in suppressing height in canna lilies and other plant species. However, excessive flowering retardation and altered leaf orientation occurred when Cutless was applied to canna lilies at rates above 50 ppm. B-Nine/ Cycocel tank mixes are effective in suppressing height in numerous plant species and are labeled for use on herbaceous crops in greenhouses. B-Nine is also labeled for use outdoors in nurseries, while Cutless is labeled for use on turfgrasses only. There are no PGRs specifically labeled for use on canna lily during nursery production.

METHODS

This study was conducted during spring and summer of 2000. One-gallon containers of dormant canna lilies (*Canna ×generalis* 'Florence Vaughan') were quartered and repotted into 3-gallon containers containing an amended pine bark:sand medium. Plants were grown in full sun with overhead irrigation applied twice daily.

Prior to PGR application, initial heights were determined and plants were grouped into height categories of short (average height of 8.7 ± 1.4 inches), intermediate (average height of 13.6 ± 1.2 inches), or tall (average height of 17.9 ± 1.5 inches). PGRs applied foliarly to plants in each height category included Cutless at 25 and 50 parts per million (ppm), B-Nine/Cycocel tank mixes at 2500/1500 and 7500/1500 ppm, and an untreated control.

Plant vegetative height, from the medium surface to the tallest vegetative point (uppermost leaf tip), was measured at 14, 30, 60, 90, and 120 days after treatment (DAT) and at first and second flower. At 60 DAT, leaf number on each flowering shoot was counted. Days to flower of the first and second inflorescence (DTFF and DTSF) were recorded daily, and flowering height was measured at first and second flower. DTFF and DTSF were defined as the number of days from PGR application until the first fully opened bloom on the first and second inflorescences, respectively. Flowering height was measured from the substrate surface to the top of the first fully opened flower of the inflorescence.

RESULTS

Both PGRs were effective in suppressing vegetative height 30 DAT through at least 90 DAT, regardless of plant height at treatment. Likewise, growth and flowering responses of plants to the three height classes were not influenced by PGR treatment.

Cutless, at 25 and 50 ppm, suppressed vegetative height 15% at 14 DAT and 28% at 30 DAT (Table 1). First flowering of most plants occurred between 30 and 60 DAT, without any flowering delay associated with Cutless (Table 2). A delay in time to second flower of 4 days occurred with Cutless-treated plants. Vegetative and flowering heights were suppressed by Cutless at both first and second flower (Table 2). Cutless suppressed vegetative height 37 to 39% at first flower and 35 to 41% at second flower compared to control plants. Flowering heights were suppressed 39 to 52% by Cutless at first flower and 36 to 49% at second flower. At first and second flower, the inflorescences of control plants extended about 6 inches above foliage, with plants treated with 25 and 50 ppm Cutless extending 2 inches and 3 inches above foliage, respectively.

Plants treated with 25 ppm Cutless appeared similar to control plants in the ratio of flowering height to foliage height, floral display, and leaf orientation. Based on observations, plants treated with the higher Cutless rate had a reduced floral display with the flowers hidden by the foliage. In a previous study, similar excessive flower height retardation was observed, but dissipated along with vegetative height suppression effects. However, the reduced floral display would be greatest during the typical retail sales window and could affect plant marketability.

Table 1. Vegetative Height for *Canna ×Generalis* 'Florence Vaughan' Treated at Three Heights with 25 and 50 Ppm Cutless and 2500/1500 and 7500/1500 ppm B-Nine/Cycocel

	Vegetative height (inches)				
	14 DAT[1]	30 DAT	60 DAT	90 DAT	120 DAT
Plant growth retardant					
Control	20.7	26.1	35.5	37.3	50.3
Cutless 25 ppm	17.6	18.9	23.4	28.5	42.6
Cutless 50 ppm	17.7	18.7	20.8	26.1	38.8
B-Nine/Cycocel 2500/1500 ppm	19.7	23.6	31.9	34.9	49.8
B-Nine/Cycocel 7500/1500 ppm	20.3	24.8	34.0	36.6	49.7
Initial plant height					
Short	15.6	20.3	29.9	33.0	45.6
Intermediate	19.5	22.4	29.2	44.2	46.4
Tall	22.4	24.5	28.7	31.9	46.3

[1] DAT = Days after treatment.

Table 2. Days to First and Second Flower and Vegetative and Flowering Height at Flower for *Canna ×Generalis* 'Florence Vaughan' Treated at Three Heights with 25 and 50 ppm Cutless and 2500/1500 and 7500/1500 ppm B-Nine/Cycocel

	First flower			Second flower		
Plant growth retardant	Days to flower	Vegetative height (in)	Flowering height (in)	Days to flower	Vegetative height (in)	Flowering height (in)
Control	50	33.5	38.7	58	34.5	40.1
Cutless 25 ppm	51	21.4	23.5	59	22.5	25.7
Cutless 50 ppm	52	20.3	18.6	62	20.6	21.1
B-Nine/Cycocel 2500/1500 ppm	50	29.8	35.9	62	32.3	38.8
B-Nine/Cycocel 7500/1500 ppm	51	32.5	39.0	58	33.0	39.8
Initial plant height						
Short	60	20.3	29.9	65	29.5	33.8
Intermediate	50	22.4	29.2	60	28.3	33.4
Tall	44	24.5	28.7	55	27.1	31.4

At 60 and 90 DAT, there were decreases of 35 to 43% (60 DAT) and 25 to 31% (90 DAT) in vegetative height [35 to 43% (60 DAT) and 25 to 31% (90 DAT)] with Cutless-treated plants. By 120 DAT, height of treated plants was suppressed 16 to 24% compared to that of control plants. At the lower Cutless rate, this equated to a difference in vegetative heights between treated and control plants of 7.5 inches, a difference not likely discernable by consumers.

B-Nine/Cycocel suppressed plant vegetative height 5 to 8% (30 DAT), 4 to 10% (60 DAT), and 1 to 6% (90 DAT) with treatment effects dissipating by 120 DAT. There was no altered leaf orientation observed in B-Nine/Cycocel treated plants; however, vegetative height suppression was minimal throughout the study and B-Nine/Cycocel may not provide adequate means of controlling height of canna lily during container production. First flower occurred between 30 and 60 DAT without any delay in flowering associated with PGR application. An acceleration in time to second flower of 4 days was observed at the lower rate of B-Nine/Cycocel. At first flower, vegetative and flowering heights of treated plants were suppressed 4 to 12% and up to 7%, respectively, compared to control plants. At 90 DAT, vegetative heights of treated plants were 6 to 7% shorter than untreated plants with similar flowering heights. Vegetative heights of B-Nine/Cycocel treated plants and controls were similar at 120 DAT.

Differences in vegetative heights among short, intermediate, and tall plants were evident at treatment and 30 DAT, but were not present at 60, 90, or 120 DAT (Table 1). Initially, the vegetative heights of short and intermediate plants were 52 and 25% less than tall plants. At 14 DAT, vegetative heights of short and intermediate plants were 30 and 13% less than tall plants. A similar trend was observed at 30 DAT with the differences diminishing to 17% (tall and short) and 9% (tall and intermediate). Between 0 and 60 DAT, short plants grew at the most rapid rate, followed in succession by intermediate and tall plants. Plants were similar in height by 60 DAT, regardless of initial height. Following 60 DAT, all plants grew at a similar rate, regardless of initial plant height.

Initial plant height affected days to first flower (Table 2). A trend of taller plants flowering first (44 and 55 days) followed by intermediate (50 and 60 days) and short (60 and 65 days) plants was observed at first and second flower, respectively. In general, second flowering occurred ten days or less after first flower. Regardless of initial height or PGR treatment, each shoot formed six or seven leaves before terminal flowering. Initially, taller plants were more physiologically advanced and, therefore, flowered sooner. Following first flower, taller plants subsequently developed new shoots faster and those new shoots flowered (second flowering) sooner than initially shorter plants.

In floriculture production, smaller plants are generally thought to be more responsive to PGRs, and as plant size increases, PGR efficacy decreases. However, initial plant height and PGRs at the rates tested suppressed height independently for canna lilies. PGR treatments were applied to plants with a range of initial heights without stunting plants shorter at treatment or requiring additional control measures for plants taller at treatment.

In summary, Cutless suppressed height throughout the 120-day study. At the lower rate, flowering height was suppressed proportionally to vegetative height and the overall floral display was not affected at either first or second flower. At the higher Cutless rate flowering height was excessively suppressed compared to the vegetative height, which resulted in flowering heights at flower lower than foliage. B-Nine/Cycocel was not effective in suppressing canna lily height to a degree that would be beneficial in container production.

These results indicate that Cutless can be applied at 25 ppm to canna lilies of varied heights and within 60 days plants will not only be shorter than control plants, but will also be more uniform in height than when initially treated. This translates into less blow-over during production and marketing, lower shipping costs, and higher quality canna lilies.

Comparison of Three Controlled-Release Nitrogen Fertilizers in Greenhouse Crop Production

Eugene K. Blythe, Joshua L. Mayfield, Barrett C. Wilson, Edgar L. Vinson III, and Jeff L. Sibley

Nitrogen fertilizers are applied to container-grown crops using a quick-release form through the irrigation water, a controlled-release form incorporated or topdressed on the growing substrate, or a combination of the two. Controlled-release fertilizers (CRF) are used most often on high-return horticultural crops, such as ornamentals and turfgrass, where their higher cost in comparison to more soluble sources is more readily justified. The use of controlled-release nitrogen fertilizers helps growers to reduce nitrogen loss from leaching. The efficient production of nursery and floricultural crops requires a fertilization program that will provide a well-timed and adequate level of nutrition throughout the production cycle.

The objectives of this study were to compare three selected CRF applied at two different nitrogen rates for effects on the growth of four common greenhouse crops and on the nitrogen content of the leachates under managed irrigation conditions as an indicator of nitrogen release.

METHODS

Liners of *Begonia x semperflorens-cultorum* cv. 'Brandy', *Euphorbia pulcherrima* cv. 'Freedom Red' (Poinsettia), *Ficus benjamina*, and *Nephrolepis exaltata* cv. 'Bostoniensis' (Boston fern) were potted into trade-gallon pots on October 2, 2000, and grown for 8 weeks under production conditions in a polyethylene-covered greenhouse at the Paterson Greenhouse Complex, Auburn University, Auburn, Alabama. The growing substrate was a 3:2:1 (v:v:v) pine bark:perlite:sand ratio amended with 1.5 pounds per cubic yard Micromax and 5 pounds per cubic yard dolomitic limestone. Air temperatures were maintained at a minimum of 70°F and a maximum of 80°F. Plants were irrigated daily with 20 fluid ounces of non-fortified tap water using individual drip emitters.

Controlled-release nitrogen was incorporated into the growing substrate prior to planting as either Mini Polymer Coated Urea (MPCU) 41-0-0, Trikote 42-0-0 polymer-coated sulfur-coated urea, or Regalite Nitroform (RN) 38-0-0, each at a low and high rate, providing total nitrogen of 1.5 or 2.5 pounds per cubic yard, respectively. Polyon 0-0-46 polymer-coated sulfate of potash was also incorporated into the growing substrate prior to planting at either a low or high rate (2.17 or 3.64 pounds per cubic yard), corresponding to the low and high nitrogen rates based on a 3:1:2: NPK ratio. Triple Superphosphate 0-46-0 was added to the growing substrate as a topdressing immediately after planting at either a low or high rate (0.55 or 0.90 pounds per cubic yard), corresponding to the low and high nitrogen rates, and again after 3 and 6 weeks at one-third the initial rate.

Leachate was collected from one replicate of each species and treatment beginning immediately after potting and thereafter for eight weeks for determination of pH and soluble salts using a YSI Model 63 pH/conductivity/temperature meter. The leachate was obtained by irrigating each plant with 5 fluid ounces of deionized water approximately two hours after the soil had been brought to container capacity by normal irrigation. Leachate samples were collected from a different replicate weekly from October 4 through November 30. Data from each treatment was averaged among the four species. Leachate samples were frozen for later determination of nitrate and ammonium levels by microscale batch technique and colorimetry.

Growth of the four crops was evaluated by comparison of overall plant size and by determination of fresh and dry weights through the harvesting of plant parts above the soil surface 40 and 57 days after planting (DAP).

RESULTS

pH. Fertilizer type and rate affected the pH of the leachates during the first 4 weeks of the trial, but not during the final 4 weeks. In general, the pH of the leachates rose quickly during the first 2 weeks, and then declined or remained stable as they approached the pH of the irrigation water (pH 6.5) by the eighth week. Trikote at low and high rates was associated with a pH that was higher than one or both of the other nitrogen fertilizers for the first 5 weeks. No adverse pH levels were noted with any of the treatments.

Soluble salts. Elevated soluble salt levels indicted a quick release of nutrients during the first week. Fertilizer type and rate continued to show effects during much of the first 3 weeks, but not at all from the fourth through the eighth week. Low and high rates of Trikote were associated with significantly higher soluble salt readings in comparison to the other treatments during the second week, and at a high rate during the third week. None of the treatments exhibited excessive levels of soluble salts during the trial. Soluble salt levels from all treatments remained at a low level from the fourth through the eighth week.

Ammonium. Nitrogen fertilizer rate and type affected ammonium levels in the leachates during the first 3 weeks and periodically during the last 5 weeks (Table 1). Ammonium levels in the leachates from the low and high levels of Trikote increased during the first 2 weeks, then diminished until absent by the eighth week. Ammonium levels in the treatment with a low rate of MPCU remained low throughout the trial, while increasing at the high rate during the first 2 weeks (to a lesser extent than the Trikote), and then decreased. Ammonium levels decreased from the outset of the trial with both rates of RN and were generally very low from the fourth through the eighth week. Among the three nitrogen fertilizers, Trikote produced significantly higher levels of ammonium in the leachates during the first 3 weeks at the high rate and the first 2 weeks at the low rate. No phytotoxicity was noted with the high levels of ammonium with the high rate of Trikote. Generally, ammonium levels suitable for production purposes were provided for the duration of the trial by the low and high rates of Trikote and by the high rate of Mini Polymer Coated Urea.

Nitrate. The effects of nitrogen fertilizer type and rate on nitrate levels in the leachates were variable during the trial (Table 2). In general, MPCU and Trikote maintained adequate levels of nitrate for plant production for most or all of the trial, while levels with RN had mostly disappeared beyond the third week. Nitrate levels from all treatments were low by the eighth week.

Growth and color. At low nitrogen fertilizer rates, plant growth of *Begonia* was greatest with Trikote followed by MPCU and lowest with RN 40 DAP. *Begonia* showed no differences in growth among the three nitrogen fertilizers or rates 57 DAP. Poinsettia exhibited more growth with low rates of MPCU and Trikote than with RN 40 DAP. There were no differences at the high rate or 57 DAP with Poinsettia. There were no differences in growth of Boston fern or with *Ficus benjamina* among the treatments 40 or 57 DAP. In general, no visual signs of nutrient deficiency

Table 1. Effect of Controlled-Release Nitrogen (CRN) Fertilizer Type and Rate on Ammonium Levels in Container Leachate

Week	0	0	1	1	2	2	3	3	4	4
CRN Rate	Low	High	Low	High	Low	High	Low	High	Low	High
CRN Type										
MPCU	19.3	8.8	18.0	37.0	31.7	76.5	31.2	52.4	11.0	24.6
Trikote	29.3	41.3	74.4	140.9	87.3	149.2	48.8	130.2	22.2	31.6
RN	45.8	111.8	32.9	50.4	18.1	49.1	11.3	18.8	1.0	4.0

Week	5	5	6	6	7	7	8	8
CRN Rate	Low	High	Low	High	Low	High	Low	High
CRN Type								
MPCU	8.2	29.3	7.5	8.9	2.4	11.1	1.2	2.7
Trikote	9.0	46.4	4.9	8.8	1.7	17.0	1.0	1.7
RN	0.7	5.4	0.5	1.7	0.2	5.1	0.3	0.8

were apparent with any of the plants during the eight weeks of the trial. Plants with Trikote as their nitrogen source appeared somewhat greener than with other treatments.

Trikote at the low rate appeared to be the most suitable of the six nitrogen fertilizer treatments tested for the production of the four crops under greenhouse production conditions, although its application to production may be limited to short-term crops. RN appeared to be the least suitable of the three products tested as most of its nitrogen was released early in the trial. None of the N-fertilizers tested would be recommended for production cycles of greater than 8 weeks. Other controlled-release products with extended release characteristics would likely be more suitable for crops with longer production cycles.

Table 2. Effect of Controlled-Release Nitrogen (CRN) Fertilizer Type and Rate on Nitrate Levels in Container Leachate

Week	0	0	1	1	2	2	3	3	4	4
CRN Rate	Low	High	Low	High	Low	High	Low	High	Low	High
CRN Type										
MPCU	9.6	68.8	47.4	71.0	9.2	60.6	30.3	57.9	16.9	18.5
Trikote	15.1	58.7	179.5	58.0	51.9	88.7	86.7	90.4	32.1	16.8
RN	22.4	103.8	63.4	93.8	11.6	32.0	51.3	23.9	9.3	5.2

Week	5	5	6	6	7	7	8	8
CRN Rate	Low	High	Low	High	Low	High	Low	High
CRN Type								
MPCU	26.5	4.1	46.3	62.4	9.9	8.3	2.4	7.3
Trikote	24.4	4.7	16.9	12.2	3.4	11.4	1.1	3.5
RN	7.6	2.7	6.7	4.0	0.2	0.6	0.4	1.3

Optimizing Fertilization Practices for 10-Inch Boston Fern Production

Charles P. Hesselein, Charles H. Gilliam, J. Raymond Kessler, Frederick C. Engle

Ten-inch Boston ferns are an important greenhouse crop, especially for smaller growers. Recently, several South Alabama Boston fern producers have had production problems. These problems, necrotic foliage and reduced root mass, have been associated with high media soluble salts. In the summer of 1999, a greenhouse test was initiated to determine optimum fertilization practices for producing Boston ferns in 10-inch hanging baskets. After querying several fern producers to determine their medium and fertilization regimes, a pine bark:peat moss medium (1:1 by volume) amended with 1.5 pounds of Micromax and 8 pounds of dolomitic limestone per cubic yard was chosen.

METHODS

On June 15, 1999, 4-inch Boston fern liners were planted into 10-inch baskets filled with the base medium amended with either 15 or 23 pounds Nutricote 18-6-8 Type 360 Day formulation per cubic yard. Plants were grown in a double layer polyethylene greenhouse under approximately 50% shade. Minimum temperatures were maintained at 50°F.

Liquid fertilizer of 0, 100 or 200 parts per million (ppm) N from Peter's General Purpose 20-10-20 soluble fertilizer was supplied to plants in one of three schemes: (1) intermittent constant liquid fertilization (100 ppm N) dependent upon weekly soluble salt measurements obtained by using a modification of the Virginia Tech Extraction Method. (Treatments reaching electrical conductivity [E.C.] readings of 0.75 mmhos, 1.5 mmhos or 2.25 mmhos were not fertilized the following week); (2) twice weekly fertilizations throughout the trial; and (3) twice weekly fertilizations during the final four weeks of the trial only. Liquid fertilization was initiated on August 13, 1999. Hanging basket ferns are generally produced suspended multi-layered from the greenhouse frame; however, due to the constraints of our irrigation system, plants in our test were grown on raised, wire-topped benches. Plants were irrigated using 2-gallon-per-hour, pressure compensated Chapin tube emitters.

Treatments were evaluated using several measurements including shoot dry weight, chlorophyll content determined by a Minolta SPAD-502 chlorophyll meter, growth index (data not presented), and foliar color rating. Only final production data collected on March 21, 2000 is presented and discussed in this article.

RESULTS

At the end of production, ferns receiving no liquid fertilization had among the lowest measurements for shoot dry weight, foliar color rating, and chlorophyll content (Table 1). For ferns in all but one of the treatments receiving liquid fertilizer for only the final month, chlorophyll content, shoot dry weight, and foliar color rating were similar to ferns receiving no liquid fertilization. However, ferns fertilized with 23 pounds per cubic yard of incorporated controlled release fertilizer and receiving liquid fertilization at 200 ppm N for only the final month of production were indistinguishable from ferns receiving liquid N throughout the study for chlorophyll content and shoot dry weight but not foliar color rating. Ferns receiving liquid N throughout the study had among the highest measurements for chlorophyll content, shoot dry weight, and foliar color rating, regardless of ppm N, soluble salt measurements (E.C. cutoff), or rate of incorporated controlled released fertilizer. Using soluble salt measurements to control the number of weeks of liquid fertilization did not reduce plant quality for any of our measurements; however, it did reduce liquid fertilization applications from 3 to 32% for five of the six treatments.

Results of this trial suggest that there are a wide range of fertilization practices available to growers to maximize Boston fern production. The grower standard in South Alabama is incorporation of 23 pounds per cubic yard Nutricote 18-6-8 Type 360 Day formulation plus twice per week liquid fertilization with 200 ppm N from a 20-10-20 or 20-20-20 soluble fertilizer throughout production. Our study demonstrates that growers could lower both their incorporated and liquid fertilizer rates and still produce similar, high-quality plants. Growers could further reduce liquid fertilizer inputs by monitoring soluble salt levels and fertilizing only when low salt readings (below 0.75 mmhos in our study) indicate the need for liquid fertilization. The data from one treatment–23 pounds per cubic yard of incorporated fertilizer plus liquid fertilizer at 200 ppm N for the last month only–indicated that it may be feasible to eliminate the liquid fertilization portion of the fertility plan until the last month or two of production.

Reducing the amount of fertilizer used by fern growers will not only lower production costs but will reduce the possibility of over fertilization problems and the potential of environmental contamination caused by the leaching of excess fertilizer from fern containers.

The Effects Of Various Fertilization Schemes On 10-Inch Hanging Basket Boston Fern Production

Liquid fertilization ppm N	Duration	Cutoff E.C. (mmhos)	Fertilizer cutoff # weeks[1]	CRF[2] (lb)	Chlorophyll content[3]	Foliar color rating[4]	Shoot dry weight (oz)
0	—			15	26.4	3.5	10.1
0	—			23	30.0	3.6	10.3
100	28 days[5]			15	29.6	3.7	9.8
200	28 days			15	31.9	3.9	8.0
100	28 days			23	29.2	3.6	9.1
200	28 days			23	33.3	4.1	12.2
100	2x per week[6]			15	34.4	4.2	14.7
200	2x per week			15	38.4	4.5	16.7
100	2x per week			23	37.7	4.2	13.8
200	2x per week			23	39.4	4.8	14.2
100	intermittent[7]	0.75	4	15	37.5	4.5	13.4
100	intermittent	0.75	10	23	36.4	4.6	14.9
100	intermittent	1.50	1	15	38.2	4.6	12.1
100	intermittent	1.50	4	23	38.7	4.5	14.4
100	intermittent	2.25	0	15	38.8	4.6	15.1
100	intermittent	2.25	1	23	37.3	4.6	14.5

[1] Number of weeks plants were not fertilized due to meeting cutoff E.C. (Maximum number of weeks of fertilization, 31 weeks.)
[2] Amount controlled release fertilizer incorporated per cubic yard media.
[3] Chlorophyll content measured using a Minolta SPAD-502 chlorophyll meter. Higher chlorophyll readings indicate greener leaves due to increased chlorophyll content.
[4] Foliar color rating scale of 1-5 where 1= white, 2= yellow, 3= light green, 4=medium green and 5=dark green.
[5] Liquid fertilization for the final four weeks of production only.
[6] Twice weekly liquid fertilization throughout production.
[7] Intermittent constant liquid fertilization dependent upon weekly soluble salt measurements. (Treatments reaching electrical conductivity (cutoff E.C.) readings were not fertilized the following week.)

INSECT, DISEASE, AND WEED CONTROL

Evaluation of Selected Insecticides on Cannas for Prevention of the Lesser Canna Leafroller

J.C. Stevenson

The lesser canna leafroller, *Geshna cannalis,* is a small moth native to Central and tropical South America and present throughout the southeastern United States. The caterpillar stage of this moth is one of the most damaging insect pests on cannas in Alabama. Mild winters favor this tropical pest. Plant damage is due to the caterpillar fastening leaf edges of new growth together before they unfurl, producing growth deformation and reduction or failure to bloom. In addition, feeding damage on mostly upper leaf surfaces contributes to the unsightly tattered appearance of infested cannas. An evaluation was undertaken at the Ornamental Horticulture Station, Mobile, Alabama, with the objective of finding chemical means of preventing damage to cannas.

METHODS

Tropicanna™ cannas, provided by PDSI, Loxley, Alabama, were divided and potted in full gallon plastic containers on March 10, 2000. The medium used was 3:1 milled pine bark:peatmoss amended with 6 pounds dolomitic lime, 2 pounds gypsum, and 14 pounds Scott's Osmocote 15-9-12 Plus per cubic yard. Before each experiment, any suspected infestation or damage was removed by pruning. Two experiments were conducted during the spring and summer of 2000. Experiment 1 (Table 1) was set up using ornamental labeled insecticides at treatment intervals of 2 and 4 weeks. Experiment 2 (Table 2) was set up similarly except the frequency of treatment applications was increased and the Pinpoint 15G treatments were changed. Because of the possibility of foliar burn from weekly Pinpoint 15G applications, only 2-week intervals were used for this pesticide in experiment 2. Evaluations were conducted by examining the plants and determining percent infested shoots.

RESULTS

Experiment 1. In experiment 1, Pinpoint 15G and Orthene 75S applied biweekly were the only treatments that provided some protection. Treatment evaluation was conducted only once, 4 weeks after test initiation. The results led us to change the frequency of treatment applications and observations for the second experiment.

Experiment 2. In experiment 2, weekly applications provided better protection than the biweekly treatments. Both treatments of Pinpoint 15G worked well in experiment 2 until the August 2 evaluation. Possible explanations for the increased infestation following the final Pinpoint 15G application includethe following: (1)Temperature of 100°F or above for 9 of the 16 days between final application and the evaluation and (2) a rain event of more than 2 inches 4 days after this application, which may have leached some of the chemical out of the pot before plant uptake. Orthene 75S and Sevin 80WP foliar sprays at weekly intervals provided the only acceptable protection at the last observation.

Cannas grow rapidly under favorable conditions. New shoots are constantly being formed, and these are the preferred oviposition sites for the lesser canna leafroller. This may be one reason for the fluctuations of the infested whorl percentage when looking at a particular insecticide treatment from count to count.

This test was carried out under maximum pest pressure from the onset. Untreated infested plants were randomly distributed throughout the test plot providing a

Table 1. The Effect of Labeled Insecticides on Prevention of Canna Leafroller (Experiment 1)

Treatment [1]	Rate/ 100 gallons	Interval (weeks)	Whorls infested[2] (%)
Pinpoint 15G	3 g/pot	2	13
Pinpoint 15G	3 g/pot	4	48
Orthene 75S	1.0 lb	2	25
Orthene 75S	1.0 lb	4	89
Sevin 80WP	0.5 lb	2	78
Sevin 80WP	0.5 lb	4	81
Mattch FE	150 fl oz	2	78
Mattch FE	150 fl oz	4	84
Knox Out 2FM	32 fl oz	2	79
Knox Out 2FM	32 fl oz	4	90
Dipel 4L	32 fl oz	2	75
Dipel 4L	32 fl oz	4	81
Untreated check	—	—	95

[1] 2-week interval treatment application: April 28 and May 12.
4-week interval treatment application: April 28.
[2] Counts taken May 26, 2000.

constant source of pest infestation. This is unlike commercial nursery operations where all plants get treated within an area, thereby lowering pest pressure. If a large, unexpected infestation occurs, it appears likely that the only good protection is weekly sprays with an efficacious chemical.

In this limited evaluation, weekly foliar sprays of Orthene 75S and Sevin 80WP provided the best protection. Biweekly applications of Pinpoint 15G at 2 and 3 grams per pot provided good protection for the first two evaluations (July 5 and 18) but not for the final evaluation (August 2). Factors that affected its activity or uptake in the August evaluation need to be identified. Future research on controlling the lesser canna leafroller will focus on evaluating other labeled material not included in this study.

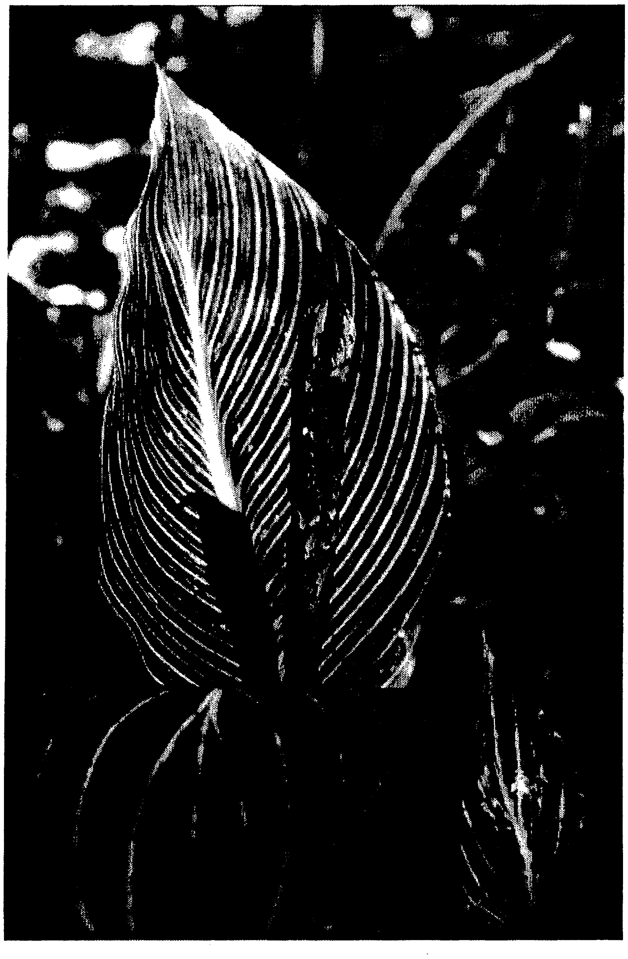
Table 2. The Effect of Labeled Insecticides on Prevention of Canna Leafroller (Experiment 2)

Treatment[1]	Rate/ 100 gallons	Interval (weeks)	Whorls infested (%) July 5	July 18	Aug 2
Pinpoint 15G	2 g/pot	2	5	0	57
Pinpoint 15G	3 g/pot	2	6	0	74
Orthene 75S	1.0 lb	1	9	8	0
Orthene 75S	1.0 lb	2	24	39	74
Sevin 80WP	0.5 lb	1	13	21	6
Sevin 80WP	0.5 lb	2	77	47	80
Mattch	150 fl oz	1	36	50	80
Mattch	150 fl oz	2	57	80	94
Knox Out 2FM	32 fl oz	1	80	93	100
Knox Out 2FM	32 fl oz	2	71	63	88
Dipel 4L	32 fl oz	1	44	73	47
Dipel 4L	32 fl oz	2	45	61	93
Untreated	—	—	79	93	89

[1]Treatments applied June 21, June 28, July 5, July 12, July 18, and July 26 on weekly sprays, and on June 21, July 5, and July 18 with biweekly sprays.

Figure 1. Lesser canna leafroller feeding damage.

Figure 2. Canna leaves fastened (tied) before unfurling.



Control of Alternaria Leaf Spot on Marigold with Heritage

A. K. Hagan, J. R. Akridge, and M. E. Rivas-Davila

Heritage 50W (azoxystrobin) is the first representative of a new class of fungicides called strobilurins, which have been marketed for use on nursery and greenhouse crops in the United States. Recent Alabama Agricultural Experiment Station (AAES) studies have shown that this fungicide has excellent activity against plant pathogenic fungi that cause damaging leaf spot and blight diseases on nursery and landscape crops. Although Heritage 50W was recently registered for the control of leaf spot and blight diseases on a wide variety of nursery and landscape crops, the efficacy of Heritage against selected plant pathogenic fungi on these crops is not well documented.

Alternaria leaf spot is a common disease in landscape plantings on African and French dwarf marigold. Symptoms first appear as tiny circular brown spots on the oldest leaves in the lower canopy. As the spots become more numerous, damaged leaves yellow, turn brown, shrivel, and die. Leaf death starts on the shoots around the base of the plant and continues until all but the youngest leaves at the shoot tips have died. Outbreaks of this disease may also damage marigold in the greenhouse. Typically, the causal fungus, *Alternaria tagetica,* is introduced into the greenhouse on seed and is transmitted into landscape plantings on diseased plants. Frequent showers or excessive overhead watering will greatly increase the severity of this disease. The efficacy of fungicides for the control of this disease is largely unknown.

The objectives of this study were to assess the performance of Heritage 50W over a range of application rates and intervals for the control of Alternaria leaf spot on marigold and to compare its activity against that of several standard fungicides.

METHODS

On May 10, 1999 and on May 2, 2000, marigold, (*Tagetes erecta*) 'Discovery Yellow', were planted in a square on 1-foot centers on raised beds in a Benndale sandy loam at the Brewton Experiment Field (Zone 8a) in Brewton, Alabama. Just before planting, 400 pounds per acre of 13-13-13 fertilizer was broadcast and incorporated. At 2-week intervals, calcium nitrate was applied at a rate of 10 pounds per acre using the drip irrigation system. The plots were watered as needed and mulched with pine bark. In 1999, fungicides were applied at 2-week intervals beginning on May 11 and ending on July 20. In the next year, applications of Heritage 50W were made at 2-, 3-, and 4-week intervals from May 24 until August 15, 2000. Eagle 40W and Daconil 2787 4F were applied at 2-week intervals. All fungicide applications were made with a CO_2-pressurized sprayer to run-off.

Disease ratings were taken July 9, 1999 and September 11, 2000. The severity of Alternaria leaf spot on marigold was assessed using a scoring system based on the Florida leaf spot rating scale where 1 = no disease, 2 = very few lesions in lower canopy, 3 = a few lesions in the lower and upper canopy, 4 = lesions in the lower and upper canopy with slight defoliation, 5 = lesions noticeable in upper canopy with some defoliation, 6 = lesions numerous with significant defoliation, 7 = lesions numerous with heavy defoliation, 8 = very numerous lesions on few remaining leaves, 9 = very few remaining leaves covered with lesions, and 10 = dead plants.

RESULTS

Despite relatively dry weather during the summer of 1999, extensive disease development was noted on the unsprayed controls as well as on some of the fungicide-treated marigolds. Substantial differences in the level of leaf spotting and disease-related leaf loss was noted among the fungicides screened (Table 1).

In the 1999 trial, Heritage 50W was the only fungicide that noticeably reduced the severity of Alternaria leaf spot when compared with disease levels on the unsprayed marigold. Damage levels on the plants treated with the fungicides 3336 4.5F, Eagle 40W, and Daconil 2787 4F were not appreciably different from those observed for the unsprayed controls. Disease severity declined as the application rate of Heritage 50W increased from 1.0 to 8.0

Table 1. Effect of Application Rate on the Control of Alternaria Leaf Spot on Marigold (1999)

Fungicide	Rate/ 100 gallons	Disease severity[1]
Unsprayed control	—	7.3
Heritage 50W	1 oz.	4.7
Heritage 50W	2 oz.	3.7
Heritage 50W	4 oz.	2.5
Heritage 50W	8 oz.	1.8
3336 4.5F	20 fl. oz.	6.2
Eagle 40W	8 oz.	6.7
Daconil 2787 4F	2 pt.	7.5

[1] Disease ratings were taken July 9, 1999. The severity of Alternaria leaf spot on marigold was assessed using a scoring system based on the 1 to 10 Florida peanut leaf spot rating scale as described in the text.

ounces of product per 100 gallons of spray volume. As indicated by disease ratings of 1.8 and 2.5, the plants treated with the 4.0- and 8.0-ounce rates of Heritage 50W suffered only light, scattered spotting of a few leaves in the lower canopy. At the lower application rates, some spotting of the leaves along with minor leaf death, particularly at the 1.0-ounce rate of Heritage 50W, could be seen. In contrast, the marigold treated with 3336 4.5F, Eagle 40W, and Daconil 2787, as well as the unsprayed controls, suffered from 50 to 75% leaf death and considerable spotting of many of the remaining leaves.

For the summer of 2000, monthly rainfall totals for June and July approached historical lows. When compared with the previous year, the onset and spread of Alternaria leaf spot was considerably slower. Noticeable symptom development was seen after more seasonal rainfall patterns resumed in August.

As was noted in the previous year, substantial differences in disease severity were noted among all of the fungicide treatments and the unsprayed controls (Table 2). Again, Heritage 50W greatly reduced the severity of Alternaria leaf spot on marigold. Application rate and treatment interval had a noticeable impact on the effectiveness of Heritage 50W against this disease. As expected, all rates of Heritage 50W gave better control of Alternaria leaf spot when applied at 2-week instead of 4-week intervals. When applied at 2-week intervals, the 4.0 ounce rate of Heritage 50W gave slightly better disease control compared to the 2.0 and the 1.0 ounce rates of the same fungicide. Symptoms on the marigold treated at 2-week intervals with Heritage 50W at the 4.0-ounce rate were restricted to light spotting of the leaves in the lower canopy. With damage ratings between 3.7 and 4.5, moderate spotting of the leaves along with light leaf death was seen on marigold treated with Heritage 50W at 4-week intervals.

When compared with the unsprayed control, substantial reductions in the severity of Alternaria leaf spot were obtained in 2000 with Eagle 40W and Daconil 2787 4F (Table 2). However, the level of disease control provided by both fungicides, when applied at 2-week intervals, was roughly similar to the results obtained with lower rates of Heritage 50W applied monthly.

In summary, Heritage 50W gave superior control of Alternaria leaf spot compared to several other selected fungicides. Typically, damage on marigold treated with Heritage 50W at 2-week intervals was limited to light leaf spotting in the lower and sometimes upper canopy. Over the 2-year test period, the 4.0-ounce rate of Heritage 50W gave consistently better control of Alternaria leaf spot than did the 1.0 and 2.0 ounce rates. Heritage 50W, when applied at the 8.0-ounce rate was highly effective against Alternaria leaf spot but the rate is twice the label rate and would be prohibitively expensive.

Table 2. Impact Of Application Rate And Interval On The Efficacy Of Heritage 50W For Control Of Alternaria Leaf Spot On Marigold (2000)

Fungicide	Rate/ 100 gallons	Application interval	Disease severity
Heritage 50W	1 oz.	2	2.6
Heritage 50W	1 oz.	3	3.5
Heritage 50W	1 oz	4	4.5
Heritage 50W	2 oz.	2	2.4
Heritage 50W	2 oz.	3	2.4
Heritage 50W	2 oz.	4	3.7
Heritage 50W	4 oz.	2	1.5
Heritage 50W	4 oz.	3	2.4
Heritage 50W	4 oz.	4	4.0
Eagle 40W	8 oz.	2	4.1
Daconil 2787 4F	2 pt.	2	4.0
Untreated control	—	—	7.1

[1] Disease ratings were taken September 11, 2000. The severity of Alternaria leaf spot on marigold was assessed using a scoring system based on the 1 to 10 Florida peanut leaf spot rating scale as described in text.

The overall performance of the registered standard fungicides was quite poor. Since 3336 4.5F and Eagle 40W are not registered for the control of diseases incited by *Alternaria* fungi, the failure of both fungicides to give effective disease was not unexpected. However, Daconil 2787 4F is registered for the control of leaf spots and blights incited by fungi in the genus *Alternaria*. The failure of this fungicide to control Alternaria leaf spot on marigold was surprising. Given the relatively high disease pressure in this trial, perhaps Daconil 2787 4F would have provided more effective disease control if the applications were made on a 7- to 10-day schedule.

Heritage 50W is the first of a new class of low-risk fungicides called strobilurins to be released for the control of a wide range of foliar and soilborne diseases on annuals, perennials, and woody plants. As was the case in previous AAES studies on vinca, the level of disease control provided by Heritage 50W was superior to that obtained with current fungicide standards. Should regulatory action by EPA limit the availability of widely used fungicides such as Daconil 2787 4F (chlorothalonil), Heritage 50W would be an effective replacement.

New Disease of Chrysanthemum Identified

Jackie Mullen, Austin K. Hagan, and Debra Carey

Chrysanthemum (*Chrysanthemum × morifolium*) is a popular bedding and potted plant in the late summer and fall. It is enjoyed because of its profusion of flowers in a wide variety of colors.

In September of 2000, premature flower browning was noted on 'Debonair' chrysanthemum in a greenhouse situation and also in a large retail outlet. The problem started with petals showing small brown spots or flecks. These specks enlarged and soon large areas of flowers or whole flowers were brown (Figure 1). Leaves did not exhibit any damage.

When a plant disease occurs, the primary interest of growers and homeowners is to control or manage the problem so that it does not continue to develop and damage more plants. Before disease control can be determined, the disease must first be identified. This report describes the investigations done to determine the cause of this flower blight and to establish that this disease had not previously been reported on chrysanthemum.

METHODS

Dying flowers were examined microscopically, and damaged tissues were placed onto several different culture media. The fungal isolate observed most frequently in cultures was identified by spore structures produced on specific sporulation-inducing culture media. A literature search indicated that this fungus had not been previously reported as a flower blight disease agent on chrysanthemum. Tests were designed to determine if the fungus isolated in culture actually caused the flower blight of chrysanthemum 'Debonair' and if other cultivars of chrysanthemum are also susceptible.

Testing of detached blossoms in the laboratory was initially performed followed by two tests involving whole plants. Seven cultivars of chrysanthemum were tested for susceptibility to the isolated fungus. These cultivars were 'Debonair' (pink decorative), 'Yellow Triumph' (yellow decorative), 'Spotlight' (pale pink decorative), 'Raquel' (dark red decorative), 'Jennifer' (bronze, two-tone decorative), 'Grace' (orange daisy), and 'Hot Salsa' (dark red daisy). With the detached blossom test, two to three detached blossoms of each cultivar were placed into two Petri dishes containing a moist piece of paper. The flowers in one dish were sprayed with a spore suspension (100,000 spores per ml) of the fungus. The second dish with flowers was sprayed with sterile water. Plates were held at 74 to 78°F for 4 days.

Whole plants with numerous flowers in 6-inch diameter pots were used for further testing, and the seven cultivars listed above were included in each test. In the first test, two plants of each cultivar were inoculated by spraying flowers and leaves thoroughly with a spore suspension as described before. Two plants of each cultivar were sprayed with sterile water and served as controls. These plants were placed in separate plastic bags, misted daily with sterile water while in bags, and held at 71 to 72°F with indirect lighting (approximately 12 hours per day) for 1 week. In a second test, plants were kept in a growth chamber room to simulate a warm, humid, wet, low-light environment. Four plants of each cultivar tested before (except 'Debonair') were inoculated as before. Also, four plants of each cultivar were sprayed with sterile water as controls. With 'Debonair', one plant was inoculated with a spore suspension and one plant was treated with sterile water as a control. Plants were held for 3 days in a growth chamber room at 71°F days, 68°F nights with a humidifier and daily misting on a plastic enclosed bench under low light with an 11-hour photoperiod.

RESULTS

Microscopic study revealed the presence of a fungus in the genus *Phytophthora*. Culture work consistently produced the fungus *Phytophthora parasitica* (identified by spore characteristics) (Figure 2), which has been reported to cause root rots, dieback, and leaf blights on many different plant species. A literature search indicated that *Phytophthora* had not been reported to cause a blossom blight on chrysanthemum. However, *P. parasitica* has been reported to cause a leaf blight when it was artificially inoculated on *Chrysanthemum × morifolium* 'Capri' and 'Vermilion' in Florida, and a closely related fungus *P. nicotiana* var. parasitica had been reported to cause a twig and leaf blight on *C. coronarium* in India.

All fungus-inoculated flowers became blighted while control flowers remained healthy. In the detached-flower tests, flowers began showing leaf spots after 3 days. Severe blight was seen after 4 to 5 days (Figure 3). With the inoculated plants held in plastic bags, spots appeared on the flowers within 2 days after inoculation (Figure 4) and a general flower blight followed quickly. With plants held in the growth chamber room, spotting began after 24 hours from inoculation and general flower blight occurred after 2 to 3 days (Figures 5, 6). *P. parasitica* was consistently isolated from blighted petals onto culture media. Only flowers became infected; no damage was seen on the foliage or shoots. These results demonstrate that the blighted flowers were caused by the fungus *Phytophthora parasitica,* which has not been previously reported to cause a flower blight disease on chrysanthemum. In addition, all seven cultivars tested were equally susceptible to infection by this fungus.

Figure 1. 'Debonair' chrysanthemum with flower blight brought for diagnosis.

Figure 2. Microscopic spore structures of the fungus *Phytophthora parasitica* produced in culture.

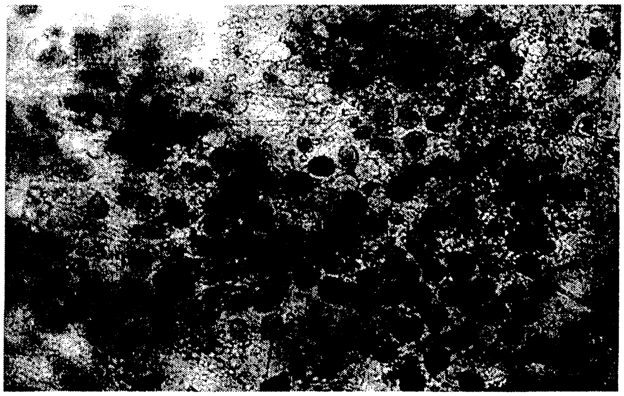


Figure 3. Detached flowers of 'Yellow Triumph' chrysanthemum 4 days after spray inoculation with *P. parasitica* spores (left) and sterile water spray (right).

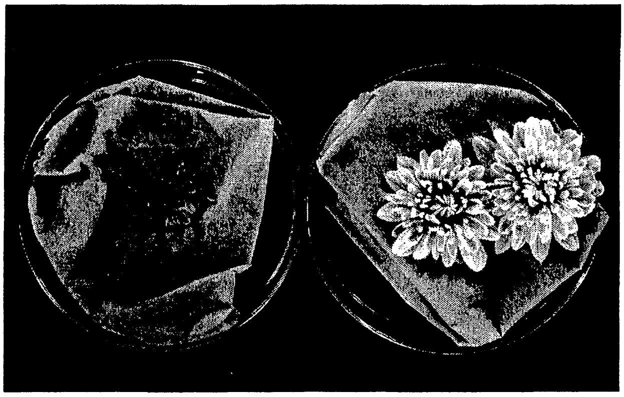


Figure 4. 'Debonair' flower just beginning to show symptoms of blight 2 days after inoculation with *P. parasitica* with subsequent holding in a plastic bag with daily misting.

Figure 5. 'Jennifer' chrysanthemums two days after inoculation with *P. parasitica* (right) and sterile water spray (left) with subsequent holding in a growth chamber room.

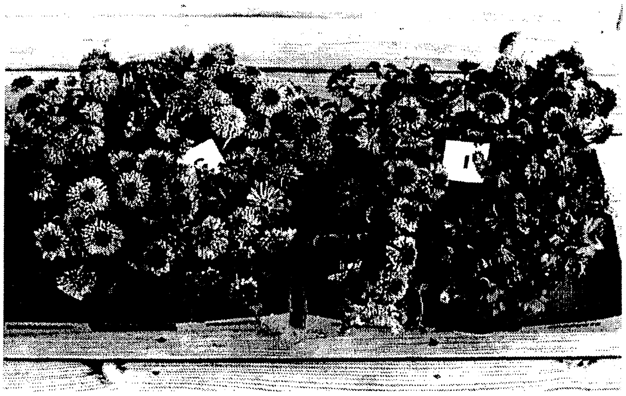
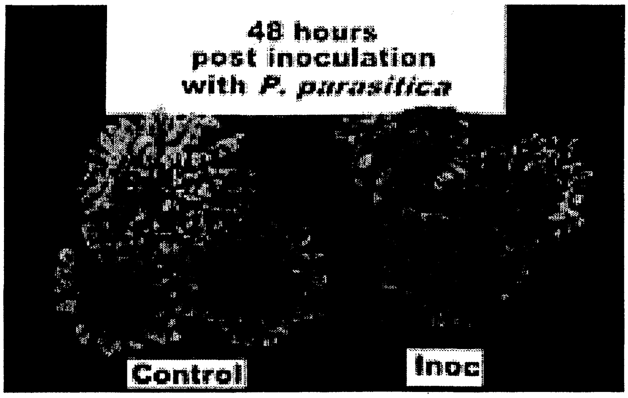


Figure 6. 'Jennifer' flowers taken from chrysanthemum plants 48 hours after inoculation with *P. parasitica* (right) and sterile water (left) with subsequent holding in a growth chamber room.



Black Spot and Cercospora Leaf Spot Resistant Shrub and Ground Cover Roses Identified

A. K Hagan, J. R. Akridge, M. E. Rivas-Davila, and J. W. Olive

In Alabama, black spot is the most widespread and common disease on the vast majority of roses and has a detrimental impact on their health and vigor. Other diseases including powdery mildew, downy mildew, and Cercospora leaf spot may also damage roses in the production nursery and the landscape. Alabama's typically wet and hot growing season, which favors rapid disease development and spread, mandates an intensive season-long fungicide spray program, especially for black spot-susceptible hybrid tea, florabunda, and grandiflora roses. Ground cover and shrub roses are not widely planted in Alabama. Consequently, their reaction to diseases is not well known. The objective of this study was to assess resistance of selected cultivars of ground cover and shrub roses to common diseases as well as their adaptability to Alabama's hot summers.

METHODS

In January 1998, bare-root roses were potted in a pine bark/peat moss mixture (3:1 v/v) amended with 14 pounds of 17-7-12 Osmocote, 6 pounds of dolomitic limestone, 2 pounds of gypsum, and 1.5 pounds of Micromax per cubic yard of potting mix. After 1 month in containers, the roses were transplanted into raised beds at the Brewton Experiment Field where the fertility and pH had been adjusted according to the results of a soil fertility test. The initial plantings of 25 selections of shrub and ground cover roses were made on January 30 and March 19, 1998. *Rosa mutabulis* (butterfly rose) was added on June 4, 1998, while 'Carefree Wonder', 'Hansa', 'Double Delight', and 'Pink Grootendorst' were planted on February 11, 1999. In March 2000, 'Betty Prior', 'Bonica', 'Double Delight', 'First Light', 'Magic Carpet', and 'Royal Bonica' were replaced with 'Ice Meidiland', 'Knock Out', 'Knox', 'Sweet Chariot', and 'Theresa Bugnet'.

Beds were mulched with aged pine bark. A drip irrigation system was installed immediately after plant establishment, and roses were watered as needed. A tank-mix of 1 pound of Gallery DF™ and 2 quarts of Surflan T/O™ per acre was broadcast over the beds early each spring for preemergent weed control. Hand weeding and directed applications of recommended rates of Roundup™ or MSMA were employed as needed for control escaped weeds. Ammonium nitrate was broadcast monthly during the growing season at the rate of 40 pounds of actual nitrogen per treated acre over the beds.

The severity of black spot and Cercospora leaf spot was rated using a modified 1 to 10 Florida peanut rating system, where 1 = no disease, 2 = very few spots in the lower canopy, 3 = a few spots in the lower and upper canopy, 4 = some light defoliation in the lower canopy with spotting in the lower and upper canopy, 5 = noticeable spotting of the leaves with moderate defoliation ($\geq$ 25%), 6 = spots numerous with significant defoliation ($\geq$ 50%), 7 = spots numerous with severe defoliation ($\geq$75%), 8 = few remaining leaves are heavy spotted with heavy defoliation ($\geq$90%), 9 = very few remaining leaves covered with spots, and 10 = plant defoliated.

Disease ratings were made on April 25, June 3, August 5, October 16, and December 3, 1998 and on March 23, May 6, June 24, August 30, and October 10, 1999. In 2000, black spot and Cercospora leaf spot severity was assessed on April 12, May 23, June 27, September 11, September 27, and November 10. Average disease rating for black spot and Cercospora leaf spot was calculated each year by dividing the total of the ratings for each disease recorded at the above dates and then dividing by the number of observations taken in that year.

RESULTS

Weather patterns have a significant impact on the spread and development of black spot and Cercospora leaf spot on rose. From May until August 1998, unusually hot and dry weather suppressed the development of both diseases. For the remainder of the summer and fall, rainfall totals were at or above historical levels and stimulated disease development. In 1999, rainfall totals were below normal from the time of leaf-out in March until near normal rainfall patterns returned in June. Rainfall totals in the spring and summer of 2000 were near historical lows, and temperatures during that time period were at or often above the historical average for Brewton.

In all three years, considerable differences in the sensitivity of ground cover and shrub roses to black spot and Cercospora leaf spot were observed. Although black spot was the most common disease, Cercospora leaf spot proved equally damaging as that disease on several cultivars. Generally, symptoms of either black spot or Cercospora leaf spot, but not both diseases, were recorded on all of the rose selections screened. Over the test period, symptoms of powdery mildew and downy mildew were noted on one or two cultivars, but damage was negligible. Surprisingly, aerial blight caused by *Rhizoctonia solani* was identified in all three years on 'Petite Pink Scotch'. In June or July, extensive and unsightly blighting of the inner canopy was noted on this rose. Symptoms of aerial blight were not observed on any other rose selection.

In 1998, black spot caused leaf spots and early leaf drop on all roses except 'Carefree Delight', 'Flower Carpet', 'Fushia Meidiland', 'White Flower Carpet', 'Happy Trails', 'The Fairy', and 'Petite Pink Scotch' (see table). Substantial differences in symptom severity were seen among the black spot-damaged roses. With disease ratings ranging between 3.0 and 3.5, 'Ralph's Creeper', 'Red Cascade', and *R. wichuraiana* suffered from light to moderate spotting of the leaves and some minor shedding of symptomatic leaves around the base of the plants. The heaviest leaf spotting and early leaf shed, which was indicated by black spot ratings of 6.0 or above, were recorded for 'Betty Prior', 'Cherry Meidiland', 'Jeeper's Creepers', 'Nearly Wild', 'Royal Bonica', and 'Sevillana'. 'Magic Carpet' proved so sensitive to black spot that all plants died. On all of the remaining roses, considerable spotting of leaves in the middle and upper canopy, as well as moderate leaf shed, was observed.

Although 'Carefree Delight', 'Flower Carpet', 'Fushia Meidiland', 'White Flower Carpet', 'Happy Trails', 'The Fairy', and 'Petite Pink Scotch' were free of black spot, symptoms of Cercospora leaf spot were noted on all of these roses. As indicated by season-long disease ratings of 3.5 to 3.8, Cercospora leaf spot-induced damage on 'Flower Carpet', 'White Flower Carpet', 'Happy Trails', and 'Fushia Meidiland' was limited to light to moderate leaf spotting and light leaf shed in the lower plant canopy (See table). Heavier leaf spotting and defoliation from Cercospora leaf spot in the lower and mid-canopy were observed on 'The Fairy', 'Petite Pink Scotch', and particularly, 'Carefree Delight'.

In 1999, considerable differences in susceptibility to either black spot or Cercospora leaf spot were again seen on the ground cover and shrub roses. Symptoms of both diseases were not found on the same rose.

The least black spot damage was noted on the newly established 'Hansa' and 'Pink Grootendorst', as well as on 'Red Cascade' and *R. wichuraiana*. With disease ratings of 2.1 to 3.2, black spot symptoms were limited to light spotting of leaves in the lower and mid-canopy, as well as minimal early leaf shed. Of the other two roses planted in 1999, the shrub rose, 'Carefree Wonder', which was moderately susceptible to black spot, suffered from less leaf spotting and defoliation than did the hybrid tea rose, 'Double Delight'. Although the black spot ratings for some roses were lower in 1999 than in the previous year, serious spotting of the leaves and extensive leaf shedding, as indicated by disease ratings of 5.0 or above, were recorded again for 'Betty Prior', 'Jeeper's Creepers', and 'Sevillana'. As was seen in the previous year, typical leaf spot and early leaf shedding commonly associated with damaging black spot outbreaks were seen on the remaining rose selections.

During the 1999 growing season, six rose selections suffered noticeable Cercospora leaf spot damage. The highest level of spotting of the leaves and early leaf shed was seen on 'Carefree Delight' and 'White Flower Carpet' (see table). As indicated by Cercospora leaf spot ratings of 3.4 to 4.3, symptoms on the remaining four roses included spotting of the leaves in the lower and upper canopy and, in several cases light leaf shed. Cercospora leaf spot was not observed on any of the roses established in 1999.

Despite an extended drought, considerable black spot and Cercospora leaf spot damage was seen on susceptible rose selections throughout much of the 2000-growing season. In fact, the seasonal damage ratings for both diseases for many rose selections were higher in 2000 than in 1999. Again, no mixed outbreaks of black spot and Cercospora leaf spot were seen.

As was the case in the previous two years, more severe black spot symptoms occurred on more rose selections than any other disease. Rose selections with the least black spot damage were 'Hansa', 'Mystic Meidiland', 'Red Cascade', *R. wichuraiana*, 'Therese Bugnet', and the newly planted 'Ice Meidiland' and 'Knock Out' (see table). For 'Ice Meidiland', 'Red Cascade', and *R. wichuraiana*, which had black spot ratings of 2.5 to 2.7, symptoms were limited to light spotting in the lower and mid-canopy, as well as very little early leaf shed. The other previously mentioned roses, with disease ratings of 3.2 to 3.6, suffered from light to moderate spotting throughout the plant canopy and some leaf loss. As indicated by black spot ratings of 6.0 or higher, defoliation levels on 'Cherry Meidiland', 'Jeeper's Creepers', 'Livin' Easy', and 'Sweet Chariot' exceeded 50%, and few of the remaining leaves were free of symptoms.

Overall, Cercospora leaf spot damage levels on ground cover and shrub roses seen in 2000 were similar to those recorded in 1999 (see table). Symptoms of this disease were again found only on the same six rose selections. Leaf spot and defoliation levels ranged from light on 'Petite Pink Scotch' to extensive on 'Carefree Delight'. None of the five rose selections planted in the winter 2000 were damaged by Cercospora leaf spot.

As expected, black spot was the most common disease seen on the 36 shrub and ground cover roses screened over the 3-year evaluation period. Repeated outbreaks of Cercospora leaf spot on six of these roses, however, suggest that this disease may be more prevalent and damaging, particularly on ground cover and shrub roses, than was previously reported. In fact, the level of leaf spotting and early leaf shed attributed to this disease was similar to that seen on roses heavily damaged by black spot. Mixed outbreaks of black spot and Cercospora leaf spot were not seen. Powdery mildew and downy mildew were seen sporadically, and damage attributed to either disease was minimal. In late spring to early summer each year, aerial blight caused by *Rhizoctonia solani* consistently destroyed the leaves in the inner canopy of 'Petite Pink Scotch'. Symptoms of this disease were not observed on any other rose selection.

A few roses proved to be resistant to both black spot and Cercospora leaf spot. Over the three-year test period, the ground cover roses *R. wichuraiana* and 'Red Cascade' suffered the least disease-related leaf spotting and early leaf shed. Typically, black spot symptoms on both roses were limited to leaf spotting and, by early fall, light shedding of the oldest leaves around the base of the plant. In two of three years, 'Mystic Meidiland', which has a shrub-type growth habit, also demonstrated partial resistance to black spot. From 1998 through 2000, no symptoms of Cercospora leaf spot were found on any of the above rose selections. Of the five rose selections established in 1999, 'Hansa' and 'Pink Grootendorst', which are shrub-type rugosa roses, had the lowest black spot ratings and both were free of Cercospora leaf spot. While leaf spot damage on both roses was light to moderate, defoliation levels gradually increased during the growing season until nearly 25% of the leaves were prematurely shed, particularly in 2000 on 'Pink Grootendorst'. The ground cover rose, 'Ice Meidiland', proved the most disease resistant of those established in 2000. Black spot damage was restricted to some spotting of the foliage in the lower and mid-canopy. As was the case with *R. wichuraiana* and 'Red Cascade', some disease-related leaf shed was also seen on this rose in Fall 2000. The above disease-resistant roses could be maintained in residential landscapes without protective fungicide treatments.

A number of rose selections proved to be highly susceptible to either black spot or Cercospora leaf spot. 'Bonica', 'Cherry Meidiland', 'Jeepers Creepers', 'Nearly Wild', 'Royal Bonica', and 'Sevillana', which consistently suffered from heavy and unsightly black spot-related leaf shed, could not be maintained in Alabama landscapes without an intensive, season-long fungicide spray program. Cercospora leaf spot was troublesome on 'Carefree Delight', 'Flower Carpet', 'Fushia Meidiland', 'Petite Pink Scotch', 'The Fairy', and 'White Flower Carpet'. As was the case with the black spot susceptible roses, these selections often required fungicide treatments to maintain plant beauty and health in landscape plantings.

In summary, the rose selections with the highest level of resistance to black spot and Cercospora leaf spot were *R. wichuraiana* and 'Red Cascade'. Other potentially disease-resistant roses, which had low black spot and Cercospora leaf spot ratings include 'Mystic Meidiland', 'Hansa', 'Pink Grootendorst', and 'Ice Meidiland'.

Average Ratings Cercospora Leaf Spot and Black Spot on Selected Ground Cover and Shrub Roses at the Brewton Experiment Field (1998 To 2000)

		Average disease rating[2]					
Rose cultivar	Rose	Cercospora leaf spot			Black spot		
	Type[1]	1998	1999	2000	1998	1999	2000
Betty Prior	S	1	1	R[5]	6.9	5.0	R
Bonica	S	1	1	R	5.6	4.8	R
Carefree Delight	S	6.2	4.9	5.6	1	1	1
Carefree Wonder	S	NP[3]	1	1	NP	4.0	4.1
Cherry Meidiland	S	1	1	1	6.1	5.0	6.3
Double Delight	HT	NP	1	R	NP	4.6	R
Fire Meidiland	GC	NP	NP	1	NP	NP	4.2
First Light	S	1	1	R	5.9	4.4	R
Flower Carpet	S	3.5	4.3	3.9	1	1	1
Fushia Meidiland	GC	4	4.2	4.3	1	1	1
Hansa	S	NP	1	1	NP	2.4	3.2
Happy Trails	GC	3.7	3.9	5.1	1	1	1
Ice Meidiland	GC	NP	NP	1	NP	NP	2.6
Jeeper's Creepers	GC	1	1	1	6.0	5.2	6.3
Kent	S	NP	NP	1	NP	NP	4.4
Knock Out	S	NP	NP	1	NP	NP	3.6
Livin'Easy	S	1	1	1	4.1	4.8	6
Magic Carpet	GC	ND[4]	ND	R	ND	ND	R
Mystic Meidiland	S	1	1	1	4.5	3.2	3.2
Nearly Wild	S	1	1	R	6.1	4.9	R
Nozomi	S	1	1	1	4.4	3.5	4.5
Pearl Sevillana	S	1	1	1	5.4	4.4	5
Petite Pink Scotch	S	ND	3.4	3.2	1	1	1
Pink Grootendorst	S	NP	1	1	NP	3.1	3.9
Ralph's Creeper	GC	1	1	1	3.5	4.2	5.6
Raven	S	NP	NP	1	NP	NP	5.1
Red Cascade	GC	1	1	1	3.2	2.2	2.7
Royal Bonica	S	1	1	R	6.5	4.8	R
Rosa mutabulis	S	1	1	1	4.1	4.4	4.9
R. wichuraiana	GC	1	1	1	3.0	2.1	2.5
Sea Foam	S	1	1	1	5.8	4.1	4.4
Sevillana	S	1	1	1	6.7	5.2	6.1
Sweet Chariot	S	NP	NP	1	NP	NP	5.9
The Fairy	S	4.8	4.2	4.9	1	1	1
Therese Bugnet	S	NP	NP	1	NP	NP	3.4
White Flower Carpet	S	3.8	5.0	4.6	1	1	1

[1]Rose type: S = shrub rose, GC = ground cover rose, HT = hybrid tea. [2]Severity of black spot and Cercospora leaf spot was rated using a 1 to 10 scale, where 1 = no disease, 2 = very few spots in the lower canopy, 3 = a few spots in the lower and upper canopy, 4 = some light defoliation in the lower canopy with spotting in the lower and upper canopy, 5 = noticeable spotting of the leaves with moderate defoliation ($\geq$ 25%), 6 = spots numerous with significant defoliation ($\geq$50%), 7 = spots numerous with severe defoliation ($\geq$75%), 8 = few remaining leaves are heavy spotted with heavy defoliation ($\geq$90%), 9 = very few remaining leaves covered with spots, and 10 = plant defoliated. [3]NP = not planted. [4]ND = no data. [5]R = removed.

Fungicides Evaluated for Control of Downy Mildew on Container-Grown Roses

A.K. Hagan, J. W. Olive, J. Stephenson, and M. E. Rivas-Davila

Downy mildew, which is caused by the fungus *Peronospora sparsa*, has devastated blocks of container-grown "Mother's Day" roses in polyhouses and outdoors. Downy mildew-damaged roses are unsightly and unmarketable. In some cases, entire blocks of container-grown roses have been killed within a week or two by downy mildew. The typical mild, cloudy, rainy spring weather patterns of the southeastern United States are especially conducive to the onset and spread of this disease. Disease development is often so explosive that nurserymen are unaware of a downy mildew outbreak until their roses drop their leaves and die. Since downy mildew is endemic to the major rose production areas in the United States, bare-root roses purchased from wholesale suppliers are the primary source of this disease.

Currently, Aliette T/O™ (fosetyl Al) and Compass 50W™ (trifloxystrobin) are registered for the control of downy mildew on rose. However, the efficacy of these fungicides against downy mildew has not been clearly established. The objective of this study was to assess the efficacy of Compass 50W and several selected experimental fungicides for the control of downy mildew on rose and to compare their effectiveness with that of Aliette T/O.

METHODS

Bare-root shrub roses 'Fushia Meidiland' and 'White Meidiland' were potted in 3-gallon containers in a pine bark/peat medium (3:1 v/v) at the Ornamental Horticulture Station in Mobile, Alabama. The potting medium was amended with 14 pounds of 17-7-12 Osmocote, 6 pounds of dolomitic limestone, 2 pounds of gypsum, and 1.5 pounds of Micromax per cubic yard. Roses were placed on an oyster shell-covered bed in full sun and watered daily in the later afternoon or early evening using overhead impact sprinklers. 'Fushia Meidiland' and 'White Meidiland' roses were used in the first (Table 1) and second (Table 2) study. Fungicides were applied before symptoms were observed to the foliage to the point of drip with a CO_2-pressurized sprayer at 7- to 28-day intervals. Symptomatic roses 'Theresa Bugnet', which were randomly distributed through both blocks, were used as an inoculum source. Disease incidence was rated in both trials on April 26 and May 11 using a rating system where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of leaves diseased or prematurely shed due to downy mildew. Only the data collected on May 11, 2000 is shown in the tables.

RESULTS

Rainfall in the Mobile area during the months of March, April, and May 2000 was well below historical norms. The unseasonably low rainfall limited not only early season disease development but also the secondary spread of the causal fungus throughout both blocks of roses. Also, the initial *P. sparsa*-infection level on the test roses apparently was low. As a result, disease intensity in this trial was not as severe as anticipated.

As compared with damage levels on the untreated control, considerable reductions in the incidence of rose downy mildew were, however, obtained on the 'Fushia Meidiland' roses with the 4.0-ounce per 100-gallon rate of Compass 50W and the Aliette T/O standard (Table 1). Overall, Aliette T/O, when applied at a rate of 5.0 pounds per 100 gallons of spray volume, gave the best control of downy mildew. As indicated by a disease rating of 1.9, downy mildew damage on the Aliette T/O-treated 'Fushia Meidiland' roses was limited to light spotting of a few, scattered leaves.

Under moderate disease pressure, the 1- and 2-ounce-per-100-gallon rates of Compass 50W did not reduce the incidence of downy mildew as compared with the unsprayed 'Fushia Meidiland' roses (Table 1). At the 4.0

Table 1. Evaluation of Compass for the Control of Downy Mildew on Container-grown 'Fushia Meidiland' Shrub Rose at the Ornamental Horticulture Station (2001)

Treatment and rate/100 gal.	Spray interval days	Disease rating[1]
Compass 50W 4.0 oz.	7	2.9
Compass 50W 1.0 oz.	14	4.4
Compass 50W 2.0 oz.	14	4.8
Compass 50W 4.0 oz.	14	3.0
Compass 50W 4.0 oz.	28	3.3
Aliette T/O 5.0 lb.	7	1.9
Untreated control	—	4.4

[1]Downy mildew incidence was rated on May 11 on a scale of 1 to 12 where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of leaves diseased or prematurely shed.

ounce per 100-gallon rate, Compass 50W did provide some protection from this disease but was not as effective in controlling downy mildew as was Aliette T/O. The unusually dry weather was most likely responsible for the similar level of disease control obtained with the 4.0 ounce per 100-gallon rate of Compass 50W when applied at 7-, 14-, and 28-day intervals. To insure control of downy mildew with Compass 50W, a 7- to 14-day application interval will likely be needed, particularly during periods of wet spring weather. Additional studies must be done to establish the efficacy of the 1.0 and 2.0 ounce rates of Compass 50W for the control of downy mildew on rose and to determine the optimum application schedule needed to control downy mildew under conditions more favorable for disease onset and spread.

In the second study, all fungicide treatments except the 0.2 pound per 100-gallon rate of the experimental fungicide SP2005 50W significantly reduced the severity of downy mildew as compared to the levels seen on the unsprayed 'White Meidiland' roses (Table 2). Damage on most of the fungicide-treated roses was limited to light spotting of the leaves near the base of the plant. The levels of disease control obtained with the experimental fungicides SP2003 56W and the 0.4-pound per 100-gallon rate of SP2005 50W were similar to those provided by both the 2.5 and 5.0 pound per 100-gallon rates of Aliette T/O. Also, Protect T/O (mancozeb) proved as effective in controlling downy mildew as Aliette T/O.

Table 2. Efficacy of Selected Experimental Fungicides for the Control of Downy Mildew on Container-grown 'White Meidiland' Shrub Rose at the Ornamental Horticulture Station (2001)

Treatment and rate/100 gal.	Spray interval days	Disease rating[1]
SP2003 56W 1.75 lb.	7	2.3
SP2005 50W 0.2 lb.	7	3.4
SP2005 50W 0.4 lb.	7	2.3
Protect T/O 1.5 lb.	7	2.1
Aliette T/O 2.5 lb.	7	2.0
Aliette T/O 5.0 lb.	7	2.5
Unsprayed control	—	4.0

[1]Downy mildew incidence was rated on May 11 on a scale of 1 to 12 where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of leaves diseased or prematurely shed.

In both studies, Aliette T/O gave effective control of rose downy mildew. In the second study, the 2.5 and 5.0 pound per 100-gallon rate controlled this disease. Additional studies will be required to confirm which rate of Aliette T/O will give consistent control downy mildew, particularly under the higher disease pressure often seen in blocks of container-grown roses. On the other hand, Compass 50W when applied at label rates failed to protect roses from downy mildew. Although some activity against downy mildew was noted at the off-label rate of 4.0 pound per 100-gallon rate, Compass 50W was not as effective as Aliette T/O in controlling this disease. In one study, the both of the experimental fungicides and Protect T/O gave the same level of protection as the current standard fungicide Aliette T/O.

In summary, downy mildew is a major threat to the beauty, health, and most importantly the marketability of container-grown "Mother's Day" roses. Given the generally favorable weather patterns for this disease across the Southeast, fungicides are a critical component of a downy mildew management program. However, little if any data are available concerning the efficacy of registered or experimental fungicides against this very destructive disease of rose. When applied on a preventive schedule, Aliette T/O protected roses from downy mildew better than Compass 50W. Two experimental fungicides and Protect T/O also demonstrated some activity against this disease.

Impact of Application Rate and Interval on the Control of Powdery Mildew and Cercospora Leaf Spot on Hydrangea with Heritage

A. K. Hagan, J. W. Olive, J. Stephenson, and L. C. Parrott, Jr.

Powdery mildew, caused by *Erysphe polygoni*, and Cercospora leaf spot (*Cercospora* spp.) are common and damaging diseases of bigleaf hydrangea (*Hydrangea macrophylla*). Powdery mildew can cause stunting and severe leaf disfiguration in the greenhouse and in the landscape. Symptoms of Cercospora leaf spot, which commonly occurs in landscape plantings of bigleaf hydrangea, include a noticeable spotting of the leaves and premature leaf shed. Both diseases can greatly reduce the aesthetic and market value of hydrangea.

Heritage 50W, which is a new strobilurin fungicide, is now marketed for use on a wide variety of nursery and greenhouse crops. A series of Alabama Agricultural Experiment Station (AAES) studies have demonstrated that Heritage 50W provides excellent control of a wide range of damaging foliar and soilborne diseases on container and field-grown annuals, perennials, and woody plants. Although Heritage 50W has been cleared for use, the impact of application and treatment interval on its effectiveness has not been clearly demonstrated.

The objectives of this study were to evaluate the efficacy of Heritage 50W over a range of application rates and intervals for the control of powdery mildew and Cercospora leaf spot on hydrangea and to compare its activity with that of registered fungicide standards.

MATERIALS

Liners of 'Nikko Blue' bigleaf hydrangea (*Hydrangea macophylla*) were potted in #1 or #2 containers in a pine bark/peat moss amended with 14 pounds of Osmocote 17-7-12, 6 pounds of dolomitic limestone, 2 pounds of gypsum, and 1.5 pounds of Micromax per cubic yard of mix. In 1998, the plants were maintained under a 40% shade cloth. Since the 1999 and 2000 studies were conducted in the late fall, the hydrangea were placed in a polyhouse. All studies were conducted at the Ornamental Horticulture Station in Mobile, Alabama. Regardless of location, the plants were watered daily with overhead impact sprinklers. The fungicides were applied to drip with a CO_2-pressurized sprayer. A non-ionic surfactant was tank-mixed with Heritage 50W and Eagle 40W at 1% v/v. Fungicide applications were made from June 2 until October 6, 1998; October 27 until December 7, 1999; and from September 22 until November 11, 2000. The incidence of powdery mildew and Cercospora leaf spot was assessed using the Barratt and Horsfall rating system where 1 = 0%, 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12 to 25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-87%, 9 = 87-94%, 10 = 94-97%, 11 = 97-100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus or displaying typical symptoms of Cercospora leaf spot. In 1998, plants were rated for powdery mildew on September 23 and for Cercospora leaf spot on November 12. In the following studies, only the incidence of powdery mildew was recorded on hydrangea on December 16, 1999 and January 5, 2001.

RESULTS

In 1998, all fungicide treatments greatly reduced the incidence of powdery mildew and Cercospora leaf spot when compared to the unsprayed control (Table 1). On the unsprayed control, the powdery mildew fungus *E. polygoni* had colonized 75 to 87% of the leaves. Later in the fall, the typical symptoms of Cercospora leaf spot were recorded on a high percentage of the leaves. Across all rates and treatment intervals, Heritage 50W completely protected hydrangea from powdery mildew and Cercospora leaf spot. No symptoms or signs of either dis-

Table 1. Efficacy of Heritage 50W Applied over a Range of Application Rates and Intervals for the Control of Powdery Mildew and Cercospora Leaf Spot on Bigleaf Hydrangea

Treatment and rate/100 gal.	Spray interval week	Disease ratings: Powdery mildew 1998[1]	Powdery mildew 1999[2]	Cercospora leaf spot 1998[1]
Untreated control	—	7.8	7.3	5.7
Heritage 50W 4.0 oz.	1	1.1	1.2	1.0
Heritage 50W 4.0 oz.	2	1.0	1.0	1.0
Heritage 50W 4.0 oz.	3	1.0	1.2	1.0
Heritage 50W 8.0 oz.	1	1.0	1.2	1.0
Heritage 50W 8.0 oz.	2	1.0	1.0	1.0
Heritage 50W 8.0 oz.	3	1.0	1.3	1.0
3336 4.5F 20 fl. oz.	1	3.3	1.0	2.8
Eagle 40W 8.0 oz.	2	1.0	1.0	1.0

[1]In 1998, plants were rated for powdery mildew on September 23 and for Cercospora leaf spot on November 12.
[2] Only the incidence of powdery mildew was recorded on hydrangea on December 16, 1999.

ease were noted on the Heritage 50W-treated plants, even on those treated at 3-week intervals with the 4.0 ounce per 100-gallon rate. Eagle 40W, when applied at 8 ounces per 100 gallon of spray volume on a 2-week schedule, proved equally effective in controlling powdery mildew and Cercospora leaf spot as all of the Heritage 50W treatments. Although symptoms or signs of both diseases were seen, damage on the 3336 4.5F-treated hydrangea was unobtrusive. However, 3336 4.5F was not as effective in controlling either powdery mildew or Cercospora leaf spot as Heritage 50W or Eagle 40W.

In the following year, the efficacy of Heritage 50W for the control of powdery mildew on hydrangea was similar to the results recorded in 1998 (Table 1). Overall, little if any colonization of the leaves by *E. polygoni* was seen on any of the Heritage 50W-treated plants. At both the 4.0 and 8.0 ounce per 100-gallon rates, Heritage 50W was equally effective in controlling powdery mildew on hydrangea when applied at 1-, 2-, and 3-week intervals. Eagle 40W and 3336 4.5F proved just as effective as Heritage 50W in protecting hydrangea from this disease.

For 2000, the application rates evaluated for activity against powdery mildew mirrored those on the Heritage 50W label. As indicated by a disease rating of 11.5 for the unsprayed control, powdery mildew pressure was much higher here than were the levels seen in the two previous trials on hydrangea (Table 2). Although the incidence of powdery mildew on the Heritage-treated plants was greatly reduced when compared with the untreated control, considerable differences in disease incidence were noted among the application rates and treatment intervals evaluated.

Table 2. Effect of Application Rate and Treatment Interval on the Control of Powdery Mildew on Bigleaf Hydrangea with Heritage 50W (2000)

Fungicide and rate/100 gal.	Spray interval week	Powdery mildew rating[1]
Untreated control	—	11.5
Heritage 50W 1.0 oz.	1	1.0
Heritage 50W 1.0 oz.	2	2.5
Heritage 50W 1.0 oz.	3	5.5
Heritage 50W 2.0 oz.	1	1.6
Heritage 50W 2.0 oz.	2	2.6
Heritage 50W 2.0 oz.	3	4.9
Heritage 50W 4.0 oz.	1	1.4
Heritage 50W 4.0 oz.	2	1.5
Heritage 50W 4.0 oz.	3	5.1
Ultrafine Sunspray Oil 1% v/v	1	3.1
Eagle 40W 8 oz.	2	1.1

[1]The incidence of powdery mildew was visually assessed on January 5, 2001.

At the 1- and 2-week treatment interval for all rates of Heritage 50W, differences in the level of disease control were relatively minor. When applied at 2-week intervals, a slight increase in leaf colonization by *E. polygoni* was, however, observed on the hydrangea treated with the 1.0 and 2.0 rates of Heritage 50W over those treated weekly with the above rates of the same fungicide. Regardless of application rate, Heritage 50W failed to effectively protect hydrangea from attack by *E. polygoni* when applied on a 3-week interval. In addition, disease ratings recorded for the plants treated every 3 weeks at the 1.0, 2.0, and 4.0 ounce per 100-gallon application rates of Heritage 50W were similar.

Ultrafine Sunspray Oil, which was applied weekly, proved slightly less effective in controlling powdery mildew than all rates of Heritage 50W applied at 2-week intervals. As indicated by a disease rating of 1.1, Eagle 40W gave excellent control of powdery mildew on hydrangea.

In summary, Heritage 50W demonstrated excellent activity against powdery mildew over a wide range of application rates and treatment intervals. At the highest labeled rate of 4.0 ounces per 100 gallons of spray volume, nearly perfect disease control was obtained with Heritage 50W applied at 3-week intervals in two of three years. Lower labeled application rates of Heritage 50W proved effective when applied at 2- but not 3-week intervals.

Typically, the level of disease control seen with the 4.0-ounce rate of Heritage 50W was comparable to that provided by the industry standard 8.0 ounce per 100 gallons of Eagle 40W. In two of three years, Heritage 50W, when applied at the above rate every 3 weeks, was as effective in controlling powdery mildew as Eagle 40W applied at 2-week intervals. Considering the heavy disease pressure in the final year of this study, Ultrafine Sunspray oil also gave good control of powdery mildew. However, weekly treatments of this fungicide would only be practical for intensively managed greenhouse-grown hydrangea.

Comparison of Compass™ with Current Fungicide Standards for the Control of Powdery Mildew on Flowering Dogwood

A. K. Hagan, M. E. Rivas-Davila, J. W. Olive, J. Stephenson, and L. C. Parrott, Jr.

Powdery mildew, which is caused by the fungus *Microsphaera pulchra*, is a common disease in landscape plantings of flowering dogwood, *Cornus florida*. Symptoms of powdery mildew include distortion or twisting of the leaves, stunting, a loss of tree vigor, and possibly death of seedling flowering dogwood. Although several powdery mildew resistant cultivars of flowering dogwood are known, the vast majority of trees found in the nursery and landscape are highly susceptible to this disease. Consequently, fungicides are a critical component of a powdery mildew control program on flowering dogwood.

Compass (trifloxystrobin) is a new strobilurin fungicide now cleared for the control of foliar diseases on a wide range of nursery and greenhouse crops. Although this fungicide does penetrate into leaf tissues, Compass 50W is not truly systemic like Banner Maxx or 3336 4.5F.

The objectives of this study were to assess the activity of Compass for the control of powdery mildew on flowering dogwood and to compare its efficacy with that of standard fungicides.

METHODS

In March 1999, the bare-root flowering dogwood 'First Lady' was potted in #3 containers in a pine bark/peat potting medium (3:1 v/v) at the Ornamental Horticulture Station in Mobile, Alabama. The medium was amended with 14 pounds of Osmocote 17-7-12, 6 pounds of dolomitic limestone, 2 pounds of gypsum, and 1.5 pounds of Micromax per cubic yard. Trees were maintained under a 47% shade cloth and irrigated daily using overhead impact sprinklers. Fungicide treatments were applied to the point of runoff with a CO_2-pressurized sprayer at the intervals listed in the table from April 12 until October 6, 1999. On July 7, plants were visually rated for disease using the Barratt and Horsfall rating system where 1 = 0%, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus. On the same day, the percentage of leaf area colonized (disease severity) was also noted using the above rating scale. On September 29, the height and caliper of each tree was recorded.

RESULTS

Compared to the unsprayed control, all fungicide treatments greatly reduced the incidence and severity of powdery mildew. As indicated by incidence and severity ratings of 12.0 and 7.7, respectively, the powdery mildew fungus *M. pulchra* heavily colonized all of the leaves on the unsprayed controls (see table). Although the percentage of colonized leaves on the fungicide-treated dogwoods was small, significant differences in both the incidence and severity of powdery mildew were noted. The incidence of powdery mildew was higher on the flowering dogwood treated bimonthly with 1- and 2-ounces-per-100-gallon rates of Compass 50W than with the same fungicide applied weekly at 0.5 ounce per 100 gallon. Fewer *M. pulchra* colonized leaves were noted on the trees treated with Banner Maxx, Eagle 40W, and Heritage 50W than with the 1-ounce-per-100-gallon rate of Compass 50W.

Control of Powdery Mildew on Flowering Dogwood with Compass 50W

Treatment and rate/100 gallons	Spray interval days	—Powdery mildew— Incidence[1]	Severity[2]	—Tree growth[3]— Height(cm)	Caliper(cm)
Compass 50W 0.5 oz.	7	1.8	1.8	141	19.0
Compass 50W 1.0 oz.	14	4.3	2.4	158	19.8
Compass 50W 2.0 oz.	14	3.0	2.0	162	21.2
Banner Maxx 5 fl. oz.	21	2.1	1.9	149	20.1
Eagle 40W 8 oz.	14	1.6	1.6	156	21.4
Heritage 50W 8 oz.	14	1.4	1.4	153	19.2
Unsprayed control	—	12.0	7.7	133	14.8

[1] Incidence of powdery mildew was visually rated using the Barratt and Horsfall rating scale where 1 = 0%, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves colonized by the powdery mildew fungus.

[2] Disease severity was estimated visually using the Barratt and Horsfall rating scale where 1 = 0%, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaf area on a tree colonized by the powdery mildew fungus.

[3] On September 29, the height and caliper for each tree was recorded.

Tree growth was adversely affected by the severe powdery mildew infection of the leaves. Height and caliper recorded for the unsprayed flowering dogwood was significantly lower than measurements noted for nearly all of the fungicide-treated trees. Only the height of the trees sprayed with the lowest rate of Compass 50W was similar to the unsprayed flowering dogwood. Generally, the height and caliper of the dogwood treated with all rates of Compass 50W were similar to those recorded for the fungicide standards.

Control of Entomosporium Leaf Spot on Photinia and Indian Hawthorn with Compass

A. K. Hagan, J. W. Olive, L. C. Parrott, Jr., and M. E. Rivas-Davila

Compass (trifloxystrobin), a new strobilurin fungicide, has been cleared for the control of anthracnose and other foliar diseases on a wide variety of annuals, perennials, and woody plants. Although this fungicide will penetrate into leaf tissues, some of the trifloxystrobin is held in the waxy layer of the leaf for redistribution. Overall, strobilurin fungicides are known for their safety to humans, other mammals, and birds, as well as for their short residual activity in soil and water.

Entomosporium leaf spot, which is caused by the fungus *Entomosporium mespili*, is a common and often damaging disease on nursery and landscape plantings of red-tip photinia (*Photinia fraseri*), Indian hawthorn (*Rhaphiolepis umbellata*), and several other members of the apple family. Leaf spot damaged plants, which are often unmarketable, are the source of this disease in residential and commercial plantings of photinia and Indian hawthorn. Typically, fungicides are applied to container stock to prevent disease outbreaks and produce spot-free plants. Previous studies have shown that Daconil 2787 (chlorothalonil) and Eagle 40W (myclobutanil) gave effective disease control on red-tip photinia.

Although Compass is registered for the control of a number of diseases on nursery and greenhouse crops, this fungicide has not been screened for the control of Entomosporium leaf spot. The objective of this study was to assess the efficacy of Compass for the control of Entomosporium leaf spot on photinia and Indian hawthorn and to compare its performance against that of several registered fungicides.

METHODS

On May 17, 1999, liners of red-tip photinia 'Birmingham' and Indian hawthorn 'Becky Lynn' were potted in 1-gallon containers in a pine bark/peat-potting medium (3:1, v/v). The medium was amended with 14 pounds of 17-7-12 Osmocote, 6 pounds of dolomitic limestone, 2 pounds of gypsum, and 1.5 pounds of Micromax per cubic yard of mix. The plants were placed on an oyster shell-covered bed in full sun and were watered daily using overhead impact sprinklers. Fungicides were applied to drip with a CO_2-pressurized sprayer at the intervals listed in the table to photinia from July 26 until November 9 and to the Indian hawthorn from July 26 until December 7, 1999. Disease incidence was rated on photinia and Indian hawthorn on October 26 and December 12, respectively, using the Barratt and Horsfall rating system where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves damaged or prematurely shed.

RESULTS

On both red-tip photinia and Indian hawthorn, reductions in the level of leaf spotting and early leaf shed were obtained with Daconil Ultrex, Banner Maxx, and both rates of Compass 50W, as compared with the unsprayed control (see table).

Control of Entomosporium Leaf Spot on Red-tip Photinia and Indian Hawthorn with Compass 50W Fungicide (1999)

Treatment and rate /100 gallons	Spray interval days	—Leaf spot incidence[1]— Photinia	Indian hawthorn
Compass 50W 0.5 oz.	7	6.6	2.8
Compass 50W 1.0 oz.	14	7.8	5.4
Banner Maxx 6 fl. oz.	21	9.6	8.8
Daconil Ultrex 1.4 lb.	14	1.2	1.0
Unsprayed control	—	10.8	11.4

[1]Entomosporium leaf spot was rated on photinia and Indian hawthorn using the Barratt and Horsfall rating system where 1 = no disease, 2 = 0 to 3%, 3 = 3 to 6%, 4 = 6 to 12%, 5 = 12 to 25%, 6 = 25 to 50%, 7 = 50 to 75%, 8 = 75 to 87%, 9 = 87 to 94%, 10 = 94 to 97%, 11 = 97 to 100%, and 12 = 100% of the leaves damaged or prematurely shed.

While Banner Maxx and Compass 50W did reduce leaf spot incidence on red-tip photinia, none of these treatments gave effective control of this disease. As indicated by disease ratings between 6.6 and 9.6, heavy leaf shed along with spotting of the remaining leaves was seen on red-tip photinia treated with Banner Maxx and Compass 50W (see table). Also, similar levels of leaf spotting and early leaf shed were recorded with the 0.5 and 1.0 ounce per 100-gallon rates of Compass 50W.

On 'Becky Lynn' Indian hawthorn, Compass 50W treatments gave better control of Entomosporium leaf spot than did Banner Maxx (see table). As indicated by a disease rating of 8.8, the Banner Maxx-treated plants suffered from extensive leaf shed and heavy spotting of the remaining leaves. The best results with Compass were obtained with weekly applications of the 0.5-ounce per 100-gallon rate. Symptoms on these plants were limited to light spotting of the leaves.

Daconil Ultrex provided excellent control of Entomosporium leaf spot on red-tip photinia and Indian hawthorn (see table). On photinia, only a few scattered spots were found on the leaves of the Daconil Ultrex-treated plants. As indicated by a disease rating of 1.0, the leaves of the Daconil Ultrex-treated Indian hawthorn were free of leaf spot symptoms.

In summary, Daconil Ultrex and other products, containing the active ingredient chlorothalonil, remain the treatment of choice for the control of Entomosporium leaf spot. Previous Alabama Agricultural Experiment Station trials have also shown that all formulations of Daconil 2787, when applied as preventive treatments will protect photinia and Indian hawthorn from this disease. Although a noticeable reduction in disease incidence was obtained with Compass 50W, particularly on Indian hawthorn, this fungicide was not as effective as Daconil Ultrex in controlling this disease. Banner Maxx, which is registered for the control of Entomosporium leaf spot on red-tip photinia at intervals up to 21 days, was ineffective against this disease.

Postemergence Control of Bittercress in Container-Grown Crops

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Hairy bittercress (*Cardamine hirsuta*) is a common weed in container nurseries. Although this weed is considered a winter annual, it has become a year-round problem in container-grown crops due to the favorable environment provided by daily overhead irrigation. A successful herbicide program for season long bittercress control requires frequent and repeated applications of a preemergence herbicide. Bittercress control can best be achieved with a weed management program consisting of herbicides in the following chemical families: diphenyl ethers, dinitroanilines, oxadiazon, or combinations of these products. However, when an effective weed management program is not maintained, bittercress can be one of the most prolific weeds to infest nursery containers. An infestation can occur during overwintering, when preemergence applications are made to containers that were not weeded, towards the end of the season as the chemical barrier from previous applications begins to deteriorate, or anytime a scheduled application is postponed or skipped. Also, many growers are reluctant to apply preemergence herbicides immediately after potting, fearing such treatments will cause root inhibition. This delay in herbicide application can often result in bittercress germination and control failure.

Since preemergence weed control programs usually fail to control all weeds, alternatives are needed for postemergence control. Several herbicides have been evaluated for postemergence grass or sedge control in container-grown crops; however, research on postemergence control of broadleaf weeds is limited. Specifically, no research has evaluated postemergence control of bittercress in container-grown crops. Therefore, the objective of this study was to evaluate herbicides for postemergence control of bittercress in container-grown crops.

METHODS

Three experiments were conducted to evaluate bittercress control with postemergence-applied herbicides. Treatments were applied with a CO_2 backpack sprayer and an 8004 flat fan nozzle. Applications were made with a pressure of 28 pounds per square inch and calibrated to deliver 20 gallons per acre.

Experiment 1. On June 25, 1997, 'Variegata' liriope (*Liriope muscari* 'Variegata') in 4 inch diameter pots from Flowerwood Nursery in Loxley, Alabama, were selected with uniform populations of bittercress (three to five bittercress plants per container) ranging from 0.2 to 0.8 inches tall. 'Big Blue' liriope (*Liriope muscari* 'Big Blue') in similar containers from Flowerwood Nursery were also treated to evaluate injury from the herbicides. Both cultivars were single bib plants divided 6 weeks prior to treatment and potted into a pine bark medium. At the time of treatment, the foliage of both cultivars was approximately 3 inches long. Plants were treated with the following herbicides: Manage at 0.031, 0.062, or 0.125 pounds active ingredient per acre (Monsanto Co., St. Louis, Missouri); Image at 0.25, 0.5, or 1.0 pounds active ingredient per acre (American Cyanamid Co., Princeton, New Jersey); Action at 0.009, 0.018, or 0.036 pounds active ingredient per acre (Novartis Crop Protection, Inc., Greensboro, North Carolina); and Resource at 0.027, 0.054, or 0.108 pounds active ingredient per acre (Valent USA, Walnut Creek, California). The low and middle rates of all treatments reflect the lower and upper limits of the manufacturers' labeled rate.

Data collected included counts of bittercress 15 and 50 days after treatment (DAT), shoot fresh weight (SFW) and shoot dry weight (SDW) of bittercress and liriope 50 DAT, and a liriope injury rating from 1 to 5 (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = dead plant) 15 DAT.

Experiment 2. On May 11, 1998, 'Big Blue' and 'Variegata' liriope were divided into single bibs and potted into trade gallon containers with a pine bark:peat moss medium (3:1 by volume) amended per cubic yard with 14 pounds of Osmocote 17-7-12, 6 pounds of dolomitic limestone, 1.5 pounds of Micromax micronutrients, and 2 pounds of gypsum.

Containers were overseeded with 15 to 20 bittercress seed per container on May 15, 1998 and placed under 47% shade. Treatments were applied on June 15, 1998, when bittercress in 'Big Blue' were 1.6 to 2.0 inches tall and beginning to flower, and bittercress in 'Variegata' were 0.8 to 1.2 inches tall and not flowering. Containers were treated with the following herbicides: Manage at 0.015, 0.031, or 0.062 pounds active ingredient per acre; Image at 0.031, 0.062, or 0.125 pounds active ingredient per acre; Trimec Southern at 0.14, 0.28, or 0.57 pounds active ingredient per acre (PBI/Gordon Corp., Kansas City, Missouri); and Gallery at 0.5, 1.0, or 2.0 pounds active ingredient per acre (DowAgrosciences, Indianapolis, Indiana).

In an attempt to avoid injury to liriope, Manage and Image rates were lowered from those in Experiment 1 so that the middle and high Manage rates reflected the manufacturer's labeled rate of 0.031 to 0.062 pounds active ingredient per acre, respectively. Image rates were lowered so that the highest rate used was one-half the manufacturer's labeled rate of 0.25 to 0.50 pounds active ingredient per acre. Trimec Southern rates were equal to or lower than the manufacturer's labeled rate of 0.57 to 1.71 pounds active ingredient per acre. Low and middle rates of Gallery represent the range in labeled rates of 0.5 to 1.0 pounds active ingredient per acre.

Gallery is labeled as a preemergence herbicide for broadleaf weed control in nursery crops, landscape plants, and established turf and was used in this test based on a suggestion from Albert Van Hoogmoed (Overlook Nursery, Mobile, Alabama) that it provided postemergence bittercress control. This suggestion was supported by research which evaluated postemergence activity of isoxaben (the active ingredient in Gallery). The study reported that isoxaben exhibited postemergence activity with both root and foliar absorption; however, potential for postemergence use may be limited due to a low rate of absorption and poor translocation.

Data collected included bittercress control ratings (0% = no injury, 100% = plant death) 7 and 15 DAT, bittercress SFW and SDW 20 DAT, and a liriope injury rating 7, 15, 30, and 60 DAT.

Experiment 3. Experiment 3 was similar to experiment 2 with the following exceptions. Containers (trade gallon) were filled with a pine bark:sand medium (7:1 by vol) amended per cubic yard with 15 pounds of Osmocote 17-7-12, 5 pounds of dolomitic limestone, and 1.5 pounds of Micromax micronutrients. Containers with no plants were over-seeded with 25 bittercress seed per container on May 15, 1998. Treatments were applied on June 10, 1998 when bittercress were between 0.2 to 0.8 inches tall and not flowering. In addition, established trade gallon 'Midnight Flare' azalea (*Rhododendron* x 'Midnight Flare') and 'China Girl' holly (*Ilex* x *meserveae* 'China Girl') were treated at the same time to evaluate crop tolerance to herbicides. At the time of treatment, 'Midnight Flare' azalea were approximately 14 inches tall and 10 inches wide, and 'China Girl' holly were 12 inches tall and 7 inches wide.

Data collected to evaluate herbicide efficacy included bittercress control 7 and 15 DAT, and bittercress SFW and SDW 20 DAT. To evaluate crop tolerance to herbicides, an injury rating on holly and azalea was recorded 7, 15, 30, 60, and 80 DAT, and a growth index [(height + width + width) ÷ 3)] of holly and azalea was recorded 80 DAT.

RESULTS

Experiment 1. At 15 DAT, Manage- and Image-treated pots had fewer bittercress per container than the non-treated control (Table 1). At 50 DAT, all rates of Manage and Image provided 100% postemergence bittercress control. Action and Resource provided no control and were, therefore, not included in subsequent tests.

Though Manage and Image treatments provided excellent bittercress control, they also caused visual injury on 'Variegata' but not 'Big Blue', and reduced SFW on both cultivars. Symptoms of injury on 'Variegata' were leaf and crown necrosis. SFW of 'Variegata' and 'Big Blue' treated with Manage were reduced by 54 and 23%, respectively, when compared to non-treated controls, and

Table 1. Postemergence Bittercress Control in Continaer-grown 'Variegata' and 'Big Blue' Liriope (Experiment 1)

Herbicide	Rate (lbs ai/ac)	Bittercress — per container — 15 DAT	Bittercress — per container — 50 DAT	Bittercress Fresh weight (g)	'Variegata' Fresh weight (g)	'Variegata' Injury[1]	'Big Blue' Fresh weight (g)	'Big Blue' Injury
Manage	0.031	0.5	0.0	0.0	4.5	2.5	11.0	1.0
Manage	0.062	0.6	0.0	0.0	5.1	2.7	10.5	1.0
Manage	0.125	0.9	0.0	0.0	4.3	2.3	10.5	1.0
Image	0.25	0.7	0.0	0.0	3.8	2.5	9.9	1.0
Image	0.50	1.1	0.0	0.0	4.4	2.7	10.0	1.0
Image	1.00	1.7	0.0	0.0	3.0	2.8	10.2	1.0
Action	0.009	3.4	5.1	1.3	6.9	1.8	13.5	1.7
Action	0.018	3.1	6.5	1.2	8.6	1.8	14.9	2.4
Action	0.036	3.6	5.4	1.2	9.9	2.2	10.7	2.4
Resource	0.027	2.5	5.7	1.9	6.2	1.3	12.3	1.8
Resource	0.054	2.0	3.0	1.2	8.4	1.6	13.0	2.4
Resource	0.108	2.3	3.7	1.7	6.9	2.0	12.2	1.7
Control		2.8	3.9	1.4	10.1	1.0	13.9	1.0

[1] Injury was recorded at 15 DAT and rated on a scale from 1 to 5 where 1 = no injurym 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.

SFW was reduced by 63 and 28%, respectively, when treated with Image.

Experiment 2. At 7 DAT, bittercress control increased with increasing rate in 'Big Blue' for each herbicide (Table 2). At 15 DAT, the two higher Manage rates (0.031 and 0.062 pounds active ingredient per acre) provided ≥90% bittercress control in 'Variegata', while the highest level of bittercress control in 'Big Blue' was 83%. These data concur with results from experiment 1 in that Manage provided excellent bittercress control; however, bittercress control with the reduced rate of Manage (0.015 pounds active ingredient per acre) was not acceptable.

In Experiment 1, Image provided complete bittercress control; however, in Experiment 2 bittercress control was ≤75%, with the exception of 0.125 pounds active ingredient per acre applied in 'Variegata', which provided 95% control.

At 7 DAT, bittercress control from Trimec Southern was promising (73 to 96% control). However, by 15 DAT bittercress appeared to be recovering from treatment with all rates of Trimec Southern except the highest rate tested (0.57 pounds active ingredient per acre) among 'Variegata'. At 15 DAT, the two higher Gallery rates (1.0 and 2.0 pounds active ingredient per acre) provided 90 and 98% bittercress control, respectively, in 'Big Blue', and 98 and 100% control, respectively, in 'Variegata' (Table 2).

While not compared statistically, bittercress control was greater in containers with 'Variegata' where bittercress were smaller (0.8 to 1.2 inches) and non-flowering when treated, compared to bittercress among 'Big Blue' where bittercress were larger (1.6 to 2.0 inches) and flowering. For example, control of more mature, flowering bittercress in 'Big Blue' declined from 7 DAT to 15 DAT with the lowest rate of all herbicides, suggesting that bittercress were recovering from those herbicide treatments. However, with non-flowering bittercress in 'Variegata', control at the same rates appeared to increase from 7 DAT to 15 DAT, with the exception of Trimec Southern. This observation may explain why growers have indicated varying degrees of success with Gallery for postemergence bittercress control.

At 7 DAT, slight injury was observed in Manage and Trimec Southern treatments. Injury was observed on both cultivars of liriope with the highest rate of Manage; however, by 15 DAT plants had recovered. Image or Gallery treatments did not injure either cultivar. At 7 DAT, Trimec Southern caused injury to 'Big Blue' and 'Variegata'. By 15 DAT, no injury symptoms were detectable on 'Variegata'; however, injury on 'Big Blue' continued through 60 DAT. Injury was characterized by necrosis at the leaf tip and twisting of the foliage and inflorescence. These data demonstrate that reducing the Manage and Image rates reduced injury compared to higher rates applied in Experiment 1.

Experiment 3. By 15 DAT, all herbicides provided about 90% or greater bittercress control (Table 3). These data concur with Experiment 2 in that when these postemergence herbicides were applied to small, non-flowering bittercress, control was excellent.

Gallery caused no visible injury or growth reduction to 'Midnight Flare' azalea. Manage at 0.062 pounds active ingredient per acre caused slight injury to 'Midnight Flare' azalea, characterized by stunting of the new foliage. This injury was not observed 7 DAT; however, injury increased gradually with time. 'Midnight Flare' azalea treated with Image showed no signs of injury 7 DAT; however, all rates provided moderate injury 15, 30, 60, and 80 DAT, characterized by chlorosis, stunting, and rosetting of the new

Table 2. Postemergence Bittercress Control in Container-grown Liriope (Experiment 2)

Herbicide	Rate	Bittercress control [1]				Liriope injury [2]							
		7 DAT		15 DAT		7 DAT		15 DAT		30 DAT		60 DAT	
	(lbs ai/ac)	BB[3]	V[4]	BB	V	BB	V	BB	V	BB	V	BB	V
Manage	0.015	52	15	14	66	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Manage	0.031	50	60	55	90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Manage	0.062	79	68	83	99	1.4	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Image	0.031	10	3	3	5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Image	0.062	25	3	6	73	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Image	0.125	75	58	43	95	1.1	1.2	1.0	1.0	1.5	1.0	1.0	1.0
Trimec Southern	0.14	73	78	55	58	1.2	1.3	1.2	1.0	1.3	1.0	1.4	1.0
Trimec Southern	0.28	82	81	50	77	1.4	1.4	1.1	1.0	1.3	1.0	1.4	1.0
Trimec Southern	0.57	96	89	72	97	1.8	1.5	1.7	1.0	2.0	1.0	1.8	1.0
Gallery	0.50	77	24	29	78	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Gallery	1.00	88	78	90	98	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Gallery	2.00	91	80	98	100	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Control		0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[1] Where 0% = no injury and 100% = plant death.
[2] Scale from 1 to 5 where 1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.
[3] BB = 'Big Blue'. [4] V = 'Variegata'.

Table 3. Postemergence Bittercress Control and Injury to Container-grown Azalea (Experiment 3)

Herbicide	Rate	Bittercress			Azalea					
		control (%)[1]		SFW[2] (g)	injury[3]					GI[4] (cm)
	(lbs ai/ac)	7 DAT	15 DAT	20 DAT	7 DAT	15 DAT	30 DAT	60 DAT	80 DAT	
Manage	0.015	9	89	1.7	1.0	1.0	1.0	1.0	1.0	46.2
Manage	0.031	7	89	0.5	1.0	1.0	1.0	1.0	1.0	42.6
Manage	0.062	48	99	0.1	1.0	1.2	1.0	1.2	1.5	43.6
Image	0.031	56	93	0.2	1.0	2.0	1.2	2.3	1.8	45.1
Image	0.062	61	100	0.0	1.0	2.0	2.2	3.0	2.7	38.7
Image	0.125	82	100	0.0	1.0	2.0	2.7	3.2	3.3	36.2
Trimec Southern	0.14	90	100	0.0	1.5	1.8	3.2	3.0	3.0	34.1
Trimec Southern	0.28	100	100	0.0	1.7	2.2	3.2	3.3	3.3	34.3
Trimec Southern	0.57	100	100	0.0	2.0	2.7	4.3	4.3	4.2	25.2
Gallery	0.50	82	94	0.1	1.0	1.0	1.0	1.0	1.0	46.4
Gallery	1.00	85	100	0.0	1.0	1.0	1.0	1.0	1.0	47.0
Gallery	2.00	84	100	0.0	1.0	1.0	1.0	1.0	1.0	38.6
Control		0	0	3.3	1.0	1.0	1.0	1.0	1.0	43.9

[1] Where 0% = no injury and 100% = plant death. [2] Shoot fresh weight.
[3] Scale from 1 to 5 where 1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.
[4] Growth index = (height + width + width) / 3.

foliage. Moderate to severe injury of 'Midnight Flare' occurred from all Trimec Southern rates. Injury from Trimec Southern was characterized by discoloration of the foliage, twisting of the stems, premature leaf drop, and in some cases plant death. Trimec Southern was the only herbicide to reduce azalea growth. 'China Girl' holly showed no visual injury or growth reduction from any herbicide treatment (data not shown).

In summary, these results show that excellent postemergence bittercress control can be obtained in container-grown landscape crops. Gallery, a preemergence-applied herbicide with a broad label for nursery and landscape crops, provided 90 to 100% bittercress control when applied to non-flowering bittercress at the label rate of 1.0 pounds active ingredient per acre. Manage and Image provided excellent control; however, slight injury occurred on landscape crops at rates necessary for bittercress control. Neither Manage nor Image are registered for use in container-grown nursery crops.

Effect of Bittercress Size and Gallery Rate on Postemergence Bittercress Control

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Previous research ("Post Emergence Control of Bittercress in Contain-Grown Crops") demonstrated that Gallery can provide excellent postemergence bittercress control; however, results appeared to vary with size and growth stage of bittercress. These data concur with grower observations that postemergence bittercress control with Gallery is variable. Other weed species respond similarly with decreasing postemergence weed control as weed size increases.

Determining if postemergence control from Gallery is influenced by bittercress size would provide useful information to nursery growers in developing a weed management strategy for postemergence bittercress control in container-grown crops. Also, subsequent preemergence bittercress control after application for postemergence bittercress control would benefit growers by providing information on residual control and offer a more flexible weed management schedule after the herbicide was applied. Therefore, the objectives of this research were to determine if postemergence bittercress control with Gallery is affected by bittercress size, and if Gallery provides continuing suppression of bittercress germination and growth.

METHODS

In both experiments, treatments were applied with a CO_2 backpack sprayer calibrated to deliver 20 gallons per acre, with an 8004 flat fan nozzle. Applications were made with a pressure of 28 pounds per square inch.

Experiment 1. On September 14, 1998, trade gallon containers were filled with a pine bark:sand medium (6:1 by volume), amended per cubic yard with 15 pounds of Osmocote 17-7-12, 5 pounds of dolomitic limestone, and 1.5 pounds of Micromax micronutrients. Three separate groups of 50 containers with no plants were overseeded with 20 bittercress seed each at 2-week intervals and placed under 47% shade with overhead irrigation. On November 11, 1998, containers were divided into three groups containing either small, intermediate, or large bittercress. Small bittercress were 0.2 to 1.2 inches tall and not flowering, intermediate bittercress were 1.6 to 2.4 inches tall with some beginning to flower, and large bittercress were 3.9 to 5.9 inches tall and flowering. Selective weeding was done prior to treatment to achieve the desired bittercress size within a container and to remove other weed species. Each container contained three to five bittercress plants.

Containers were treated with herbicides on November 11, 1998. Irrigation was withheld for 20 hours, and then the daily irrigation schedule resumed. Treatments included Gallery applied at 0.5, 1.0, or 2.0 pounds active ingredient per acre, Image (American Cyanamid Co., Princeton, New Jersey) applied at 0.06 pound active ingredient per acre, and a non-treated control. Low and middle Gallery rates represent the labeled rate. Image was used at a rate shown to be effective in previous work.

To evaluate postemergence bittercress control, bittercress control ratings (0% = no injury, 100% = plant death) were made 7, 14, 21, and 28 days after treatment (DAT); and bittercress shoot fresh weight (SFW) and shoot dry weight (SDW) were determined 28 DAT.

Experiment 2. Experiment 2 was similar to Experiment 1 with the following exceptions. On January 19, 1999, 4-inch diameter pots of 'Natchez' crapemyrtle (*Lagerstroemia indica* L. 'Natchez') were potted into 1-gallon containers with the same medium used in Experiment 1. Plants were placed in full sun and allowed to become infested with natural populations of bittercress. On April 7, 1999, plants were divided into three groups according to bittercress size (characterized as small, intermediate, and large) and treated. Small bittercress were 0.4 to 2.0 inches tall and not flowering, intermediate bittercress were 4.0 to 4.8 inches tall and flowering, and large bittercress were 8.0 to 8.7 inches tall, flowering and bearing seed. At the time of herbicide application, 'Natchez' crapemyrtle were 14 to 18 inches tall and beginning to leaf out.

Data collected for postemergence bittercress control included bittercress control ratings 7 and 14 DAT, and bittercress SFW and SDW 21 DAT. Subsequent preemergence bittercress control was evaluated by counting the number of bittercress per container 60 DAT. Injury to crapemyrtle was evaluated 7, 14, 21, 30, and 60 DAT on a scale of 1 to 5 (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death).

RESULTS

Experiment 1. At 14 and 21 DAT, the low Gallery rate (0.5 pound active ingredient per acre) provided greater control of intermediate size bittercress compared to small and large bittercress. On all dates, when Gallery was applied at 1.0 pounds active ingredient per acre, greater control was observed with either small or intermediate size bittercress than with large bittercress. There were no differences in control due to bittercress size when Gallery was applied at 2.0 pounds active ingredient per acre. At 28 DAT, control of all bittercress increased with increasing Gallery rate. Bittercress control was less than 52% with the low Gallery rate regardless of bittercress size. Gallery applied at 1.0 pound active ingredient per acre provided 90% control of small and intermediate bittercress, but only 43% control of large bittercress. The high Gallery rate provided 86% or greater control across all bittercress sizes. At 21 and 28 DAT Image provided greater control of small and intermediate bittercress than of large bittercress (Table 1).

Gallery rate had no effect on bittercress SFW (Table 2). Bittercress that were small or intermediate in size at the time of treatment had similar SFW that were 90% smaller than similar sized non-treated controls, while bittercress that were large at the time of treatment had SFW that were only 59% smaller than non-treated controls.

The authors observed that Image controlled bittercress more rapidly than Gallery. Bittercress treated with Image dessicated by 15 DAT, while bittercress treated with Gallery gradually declined from 15 to 28 DAT. At 15 DAT, bittercress control from Image ranged from 75 to 93%, while control from Gallery was 60% or less (Table 1). By 21 DAT, bittercress control from Image was 88% or greater while control from Gallery improved, but still varied from 20 to 82%. Bittercress treated with Image had SFW 87% smaller than bittercress treated with Gallery (Table 2), partly as a result of rapid foliar dessication.

Experiment 2. Similar to Experiment 1, bittercress control was influenced by bittercress size and Gallery rate. At 14 DAT, bittercress control increased with increasing Gallery rate (Table 3). Bittercress size at the time of treatment influenced the degree of control from Gallery, with the greatest control occurring among smaller, non-flowering bittercress (7 and 14 DAT). At 14 DAT, Gallery provided 92% control of small bittercress, 71% control of intermediate size bittercress, and 48% control of large bittercress. Results from Experiments 1 and 2 concur with other research concerning the effect of weed size on postemergence herbicide efficacy, in that with other postemergence herbicides weed control of small weeds was most effective, and control decreased as weed size increased.

Bittercress SFW and SDW were not affected by increasing the rate of Gallery. However, bittercress size at the time of Gallery application resulted in SFW and SDW trends similar to those with bittercress control; large bittercress were more difficult to control. With small bittercress, SFW and SDW were negligible, while among large bittercress SFW and SDW were 0.11 and 0.02 pounds, respectively. Bittercress that were large when treated had SFW only 12% smaller than similar size non-treated controls. These data concur with results in Experiment 1 in that large bittercress were more difficult to control.

There is a low rate of absorption and poor translocation with foliar-applied Gallery. Percent coverage of the plant surface should have been higher with smaller bittercress than larger bittercress because more of the foliage would have been exposed to the fine layer of spray provided from applications calibrated to deliver 20 gallons per acre. Increased percent coverage could have resulted in a higher proportion of the plant absorbing Gallery, and thus better postemergence control. Also, because more plant metabolites move to flowering structures as flowering is initiated, control may have been increased by treating nonflowering bittercress.

Subsequent preemergence bittercress control was not affected by Gallery rate, but was influenced by bittercress size at the time of treatment. There were three times more bittercress in containers with large bittercress at the time of treatment than when small or intermediate size bittercress were present at the time of treatment; however, subsequent preemergence control was unacceptable in all treatments. This increased population was probably due to greater weed pressure from seed dispersal of seeding plants. Previous research has demonstrated that less effective preemergence weed control occurs

Table 1. Effect of Gallery Rate and Bittercress Size on Postemergence Bittercress Control (Experiment 1)

	Bittercress size	Non-treated control	—Bittercress shoot injury (%)[1]— Image 0.05[2]	Gallery 0.5	Gallery 1.0	Gallery 2.0
14 DAT[3]	Small (0.2 to 1.2 inches)	0	75	23	53	55
	Intermediate (1.6 to 2.4 inches)	0	93	40	60	46
	Large (3.9 to 5.9 inches)	0	75	19	24	40
21 DAT	Small (0.2 to 1.2 inches)	0	99	30	68	82
	Intermediate (1.6 to 2.4 inches)	0	98	52	74	78
	Large (3.9 to 5.9 inches)	0	88	20	40	69
28 DAT	Small (0.2 to 1.2 inches)	0	100	35	90	91
	Intermediate (1.6 to 2.4 inches)	0	100	40	90	86
	Large (3.9 to 5.9 inches)	0	96	16	43	86

[1] Where 0% = no injury and 100% = plant death.
[2] Herbicide rates in pounds ai/ac.
[3] DAT = Days after treatment.

under heavy weed pressure. Also, greater interception of Gallery by large bittercress plants compared to smaller bittercress plants could have reduced preemergence control due to less herbicide reaching the container substrate surface.

There were no signs of injury or growth reduction in 'Natchez' crapemyrtle from any treatment (data not shown). Many plant species have tolerance to Gallery, making it ideal for postemergence control of bittercress in container-grown crops.

In summary, small non-flowering bittercress (less than 2 inches tall) are more effectively controlled by postemergence Gallery applications than large flowering bittercress. As bittercress grew and matured, postemergence control became more difficult and higher rates were necessary for adequate control. There was no injury on plants tested. This provides nurserymen with another weed management tool when preemergence herbicide programs fail to provide complete bittercress control.

Table 2. Effect of Herbicide and Bittercress Size on Shoot Fresh Weight and Shoot Dry Weight (Experiment 1)

Herbicide	Rate (lbs ai/ac)	—Bittercress— Fresh weight[1]	Dry weight
Gallery	0.5	10.3	1.5
Gallery	1.0	10.0	1.5
Gallery	2.0	6.6	1.0
	Bittercress size		
Gallery	Small (0.2 to 1.2 inches)	1.4	0.3
	Intermediate (1.6 to 2.4 inches)	5.8	0.9
	Large (3.9 to 5.9 inches)	18.4	2.7
Image	Small (0.2 to 1.2 inches)	0.0	0.0
	Intermediate (1.6 to 2.4 inches)	0.0	0.0
	Large (3.9 to 5.9 inches)	3.2	0.7
Control	Small (0.2 to 1.2 inches)	13.5	1.2
	Intermediate (1.6 to 2.4 inches)	58.5	5.4
	Large (3.9 to 5.9 inches)	45.2	5.2

[1] Weights are in grams.

Table 3. Effect of Gallery Rate and Bittercress Size on Postemergence Bittercress Controland Subseqent Preemergence Bittercress Control (Experiment 2)

		Bittercress				
Herbicide	Rate (lbs ai/ac)	–Shoot injury (%)[1]– 7 DAT[2]	14 DAT	Fresh weight (g)	Dry weight (g)	Per container 60 DAT
Gallery	0.5	56	63	23.3	3.5	5.6
Gallery	1.0	61	72	16.6	2.9	4.6
Gallery	2.0	60	75	18.7	3.0	9.5
	Bittercress size					
14 DAT	Small (0.4 to 2.0 inches)	84	92	0.3	0.0	4.0
	Intermediate (4.0 to 4.8 inches)	65	71	10.1	1.6	3.9
	Large (8.0 to 8.7 inches)	29	48	48.1	7.7	11.7
21 DAT	Small (0.2 to 1.2 inches)	90	99	0.0	0.0	11.0
	Intermediate (1.6 to 2.4 inches)	66	92	7.3	1.3	6.6
	Large (3.9 to 5.9 inches)	51	83	25.1	4.8	8.4
28 DAT	Small (0.2 to 1.2 inches)	0	0	16.7	2.4	8.9
	Intermediate (1.6 to 2.4 inches)	0	0	33.8	5.4	23.5
	Large (3.9 to 5.9 inches)	0	0	54.9	9.3	21.4

[1] Where 0% = no injury and 100% = plant death.
[2] DAT = Days after treatment.