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Food and Environment
Agricultural Experiment Station

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Nursery and Landscape Program
2017 Research Report

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UK Nursery and Landscape Program

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About the Cover

Cephalotaxus harrintonia 'Duke Gardens', with the common name Duke Gardens Japanese plum yew, is a dioecious coniferous evergreen shrub known for its deer resistance. Well-known as a filler plant with its 2 to 3 foot height and 3 to 4 foot or more width, it can be used in many landscape settings. It is frequently seen in massed groups to establish a base for trees and larger shrubs. Rarely a focal point or seasonal interest plant, its unique evergreen foliage is used in year-round accent or counterpoint landscape features.

Dirr reported the original plant in Duke Gardens, Durham, NC, at over 8 feet tall with greater spread. 'Duke Gardens' has very lustrous foliage that holds up well in the heat and was reported by Buddy Hubbuch to have survived the severe 1990s freezes to -24°F in Bernheim Arboretum. Buddy shared so much information with so many people it seems we all report similar statements relative to cold tolerance. We count on University of Georgia Emeritus Professor and author of the *Manual of Woody Landscape Plants* Michael A. Dirr for heat-tolerance reports.

Nursery and Landscape Program

Contents

Nursery 'Duke' Blueberry Plant Production Report

Zenaida Viloria, Daniel Becker, Dwight Wolfe, Virginia Travis, June Johnston, and Winston Dunwell, Horticulture

Nature of the Work

Blueberry nurserymen are facing substrate, fertilization and irrigation problems in Kentucky. Substrate compaction (Figure 1A) and scarce and irregular plant growth (Figure 1B) were observed in blueberry nurseries in spring 2017. Blueberry has superficial fibrous roots; any water excess or deficit threatens its growth and development. For a two-year-old blueberry, a gallon of water per day is recommended (Nesbitt et al., 2013); however, this volume depends upon the soil type and climate conditions. Irrigation research in container-grown blueberry is essential to determine the right amount of water for maximum growth and production and to reduce the incidence of root rot (Fulcher et al., 2015). Furthermore, a selection of soilless mix that provides balanced air:water ratio and nutrient retention is also critical to promote plant growth and reduce soil-borne pathogens. Slow release or controlled release fertilizer at low or medium rate is recommended for young highbush blueberry to reduce risks of plant burning. Fertilizer rate for container-grown southern highbush blueberry seems to be cultivar depended (Wilber and Williamson, 2008). Fertilizer type and rate must be adjusted to plant requirements and environmental conditions.

This preliminary study was planned to determine the Osmocote PLUS 15-9-12 (7-9 months at 70°F) rate and application number for second-year nursery blueberry production.

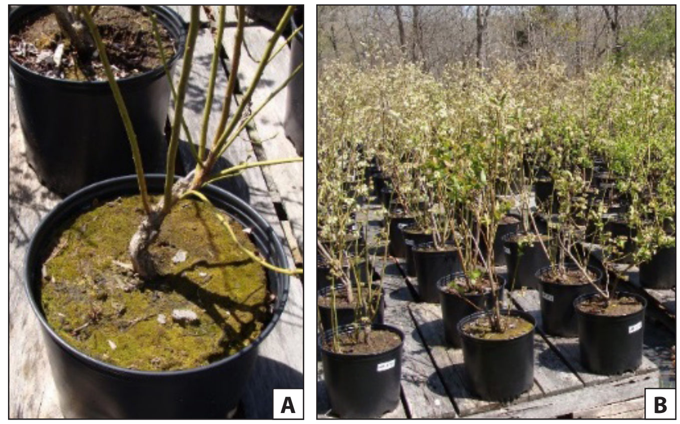

Figure 1. Nursery blueberry grown in one-gallon container. **A:** Compact soilless mix. **B:** Irregular and scarce spring growth.

Figure 2. Second-year nursery blueberries grown in 15-gallon container.

Material and Methods

One-year-old 'Duke' blueberry plants were grown in 3-gallon containers in 2016. In May 2017, for the second year of nursery production, plants were transplanted into 15-gallon containers with pine bark as a substrate. Osmocote PLUS 15-9-12 (7-9 months at 70°F) was top-dressed at 200 or 300 g/Pot. Each rate was applied once or split into two applications during the growing season to evaluate a total of four treatments. The first application was completed on June 5 and the second was done on August 3. Each treatment was applied randomly to 17 plants. The Decagon PlantPoint™ moisture sensor was used to automatically control the irrigation system.

Plant height and cane number were measured at the beginning and end of this experiment. Plant height was measured by choosing the tallest cane and measuring it from the ground level until the insertion of the newest leaves. Cane numbers were counted taking into account canes that emerged below the first 5 cm above the ground. Soil electrical conductivity (EC) and pH were determined at the end of the growing season, November 14.

Table 1. Growth of two-year-old 'Duke' blueberry fertilized at low and high Osmocote PLUS 15-9-12 rates in one or two applications.

Treatment		Initial		Final		Increase (%)			
Rate (g/pot)	Application	Canes #	Height (cm)	Canes #	Height (cm)	Canes	Height	EC (µS/cm)	pH
200	1	3.41	53.52	5.35	115.37	52.88	31.38	385	4.45
200	2	3.35	55.31	5.41	116.01	51.79	33.88	570	4.45
300	1	3.05	47.68	5.65	112.25	57.46	38.84	685	4.65
300	2	1.94	48.61	4.47	116.01	57.67	49.70	510	5.15

Results and Discussion

The increase percentage of cane number was higher in plants fertilized with 300 g/pot Osmocote (Table 1). The number of fertilizer applications did not affect the percentage of increase of the number of canes at the end of the growing season. Similarly, the percentage of plant height increase was higher when plants received the highest fertilizer rate, with a trend to develop bigger plants when the fertilizer rate was split into two applications. The plants showed growth until early November. It is likely that the second application stimulates the growth of the canes by the end of the growing season while the sprouting of new canes or activation of new buds occurs earlier. The pH and EC at the end of the season were in the range recommended for highbush (Table 1) even though the water was alkaline (pH = 7.1) with high salt content (EC = 220 µS/cm). The EC level for blueberry grown in pine bark must be in the range of 500-750 µS/cm (Krewer and Ruter, 2012).

Overall, the plants grew well (Figure 2), 'Duke' blueberry is susceptible to botryosphaeria stem blight (*Botryosphaeria dothidea*), and in fact this disease affected plants in spring. It was controlled by carefully pruning the affected branches with sanitized pruners. Low population of Japanese beetles was detected in late June and controlled with two Carbaryl-4 sprays.

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New Controlled-release Fertilizer Coating Technologies and Fertilizer Blends Affect Plant Growth and Leachate Electrical Conductivity and pH

Carey Grable, Joshua Knight, and Dewayne L. Ingram, Horticulture

Nature of Work

Common fertilization strategies in container production systems include controlled-release fertilizers (CRF). Resin or polymer coatings allow a release of nutrients over time. The composition and thickness of the coating dictate release rate and longevity (Goertz, 1993; Yeager and Cashion, 1993). Substrate temperature differs by climate and impacts the release rate (Cabrera, 1997). A CRF may be rated at 5- to 6-month longevity at 70°F, but is only rated 4 to 5 months at an average 80°F temperature. At a cooler 60°F average, this product may be rated for 6 to 7 months of release. Blends of release patterns have been customized for specific applications based on release patterns (Medina et al., 2008). New polymer technologies for coating the fertilizers are resulting in CRF with a wider range of release rate. The objective of this study was to determine the effects of three application rates of four formulations of CRF, including two with new polymer coating technology, on leachate pH and electrical conductivity, and plant growth of two species of woody plants.

Materials and Methods

Double Play® Pink Japanese spirea (*Spiraea japonica* ‹SMNSJMFP›, USPP 26,995) and Emerald arbovitae (*Thuja occidentalis* 'Smaragd') were provided as 2¼-inch liners by Spring Meadow Nursery, Grand Haven, MI and transplanted to #2 containers. Plants were grown on a gravel bed in full sun under overhead irrigation in Lexington, KY. The irrigation water was from a municipal source with a pH of 7.1 to 7.8 and alkalinity of 64 to 102 mg•L^{-1} during the experiment. Transplanting took place on 1 June 2016 for the arbovitae and 21 June 2016 for the Japanese spirea. Plants were grown in a substrate consisting of pine bark, peat, and sand (Morton's Nursery Mix; Morton's Horticultural Products, McMinnville, TN), with a lime rate of 10 lb/yard. The containers were top dressed with two rates of four different blends of CRF (31 and 47 g per #2 container; corresponding to the low and medium manufacturer recommended rates), plus a control treatment (0 g) for total of 9 treatments, with 10 replicate plants of each species. Fertilizer 1 and fertilizer 2 were prototype blends with different experimental polymer coatings. Fertilizer 1 was a 16-8-10 +1.8 magnesium (Mg) + trace elements. Fertilizer 2 was a 18-7-10 +1.8 magnesium (Mg) + trace elements. Fertilizer 3 was Osmocote Blend 18-5-8 +1.1calcium (Ca) +1.4Mg +5.8S + trace elements, which combined 100 percent resin coated prills with E-max Release Technology™ polymer coating. Fertilizer 4 was commercially available Osmocote Plus 15-9-12 +1.3Mg +6 sulfur (S) + trace elements.

Substrate electrical conductivity (EC) and pH were recorded using the pour-through leachate extraction technique (LeBude and Bilderback, 2009) on 20 June, 11 July, 1 August, and 23 August 2016 for the arbovitae, and 7 July, 25 July, 15 August, and 8 Sept. for the Japanese spirea. The experiment was concluded 18 Oct. 2016. Plant growth data were subjected to analysis of variance (Proc GLM) to determine statistical differences for main effects and interactions and Duncan's multiple range test ($\alpha = 0.05$) to separate treatment means (SAS version 9.1, SAS Institute, Cary, NC). Repeated measures analysis (Proc Glimmix) was conducted to elucidate leachate EC and pH differences due to treatment over time.

Results and Discussion

Japanese spirea

At the conclusion of the experiment, only the no-fertilizer control plants were not saleable. Japanese spirea shoot dry weights were greatest for fertilizers 1 (59.3g) and 2 (63.6g) and lowest for fertilizers 3 (53.5g) and 4 (53.6g). Shoot dry weight for the two higher application rates resulted in similar shoot dry weight. Quality ratings for above ground growth were similar between fertilizers 1, 2, and 4 and all were higher than for fertilizer 3.

Two weeks after treatment, leachate EC averaged 1.49 mS•cm^{-1} across all fertilizers and rates. However, the highest EC was 2.14 mS•cm^{-1} measured in plants receiving fertilizer 3, while all other treatments were not different from each other (Figure 1). Leachate EC for all the fertilizer treatments were similar at week 5. By week 8, EC for plants receiving fertilizers 1, 2, and 4 were all similar, but higher than plants receiving fertilizer 3. EC measurements at week 12 associated with fertilizers 2 and 4 were still higher than for fertilizer 3 with EC from fertilizer 1 being intermediate. Leachate EC generally increased with Rate increases across all fertilizer formulations (Figure 2).

The average leachate pH was 6.32 at week 2 and increased throughout the experiment, with an average of 7.51 at week 12. Fertilizer 3 had the lowest pH at weeks 2 and 5, with no difference at weeks 8 or 12. The lower pH at weeks 2 and 5 for fertilizer 3 corresponds to the quicker nutrient release rate as measured by pour-through EC. Leachate pH generally decreased as fertilizer rate increased.

Arbovitae

Only the no-fertilizer control arborvitae plants were not saleable. Dry weights of above ground growth were similar after 20 weeks for fertilizers 1 (49.7g), 2 (50.8g), and 3 (46.0), and were all higher than shoot dry weights for plants receiving fertilizer 4 (40.8g). Dry weight of roots for plants treated with fertilizer 3 resulted in the highest root dry weight. Higher fertilizer application rates resulted in higher above ground and root growth. It appears that increasing fertilizer rate favored shoot growth over root growth in arbovitae.

Leachate EC averaged 1.63 mS•cm^{-1} across all treatments at week 3; however, the EC for plants receiving fertilizer 3 (2.46 mS•cm^{-1}) was higher than for plants receiving fertilizers 1, 2, and 4, which were similar at that time (Figure 3). EC due to fertilizer 1 was still lower than fertilizer 3 at week 6 while the effect of fertilizers 2 and 4 were intermediate and similar to each other. Plants with fertilizer 3 had the lowest EC at week 12 and fertilizer 1 had the highest EC with EC due to fertilizers 2 and 4 being intermediate. As was true for spirea, the leachate EC for arbovitae receiving fertilizer 3 changed the most over the length of the experiment compared to the other fertilizers. EC was higher with increasing Rate at each measurement date.

Leachate pH generally decreased from week 3 through week 9 for fertilizers 1, 2, and 4 (Figure 4). Leachate pH for fertilizer 3 was lower than the other fertilizers at weeks 3 and 9 but were similar to fertilizers 2 and 4 at week 9. Only fertilizer 1 resulted in a lower pH compared to the other fertilizer treatments at week 12. Leachate pH averaged 6.48 at week 3 and 6.32 by week 12 across Rate. The pH due to the two higher Rates were similar to each other and lower than the 0g rate at all dates.

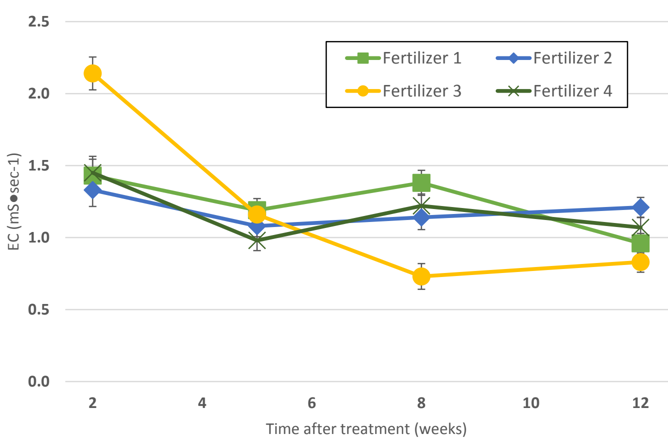

Figure 1. Leachate electrical conductivity (EC) in 'Double Play Pink' Japanese spirea as affected by controlled-release fertilizers. Fertilizer 1 (16-8-10) and fertilizer 2 (18-7-10) were prototype blends with different experimental polymer coatings. Fertilizer 3 was a blend of 18-5-8, which combined 100 percent resin-coated prills with a polymer coating. Fertilizer 4 was Osmocote Plus 15-9-12. Error bars about each mean are SE; 1 g = 0.0353 oz, 1 mS*cm^{-1} = 1 mmho*cm^{-1}.

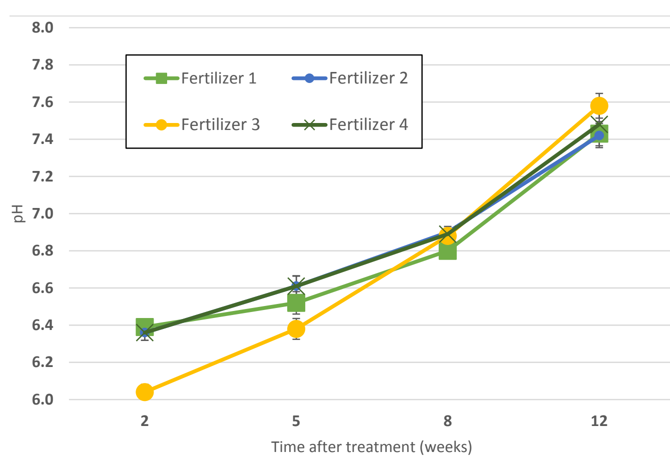

Figure 2. Leachate pH in 'Double Play Pink' Japanese spirea as affected by controlled-release fertilizers. Fertilizer 1 (16-8-10) and fertilizer 2 (18-7-10) were prototype blends with different experimental polymer coatings. Fertilizer 3 was a blend of 18-5-8, which combined 100 percent resin-coated prills with a polymer coating. Fertilizer 4 was Osmocote Plus 15-9-12. Error bars about each mean are SE; 1 g = 0.0353 oz, 1 mS*cm^{-1} = 1 mmho*cm^{-1}.

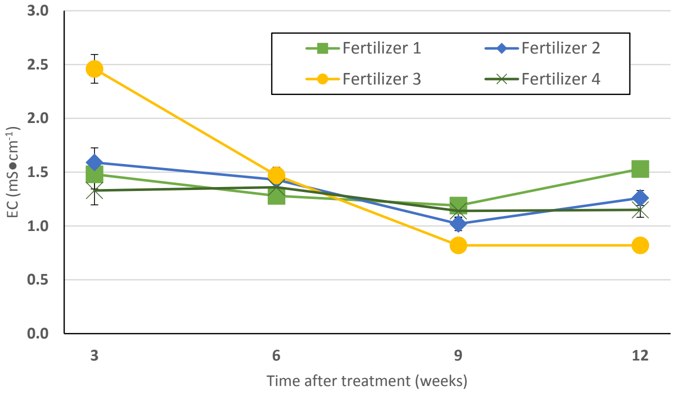

Figure 3. Leachate electrical conductivity (EC) in 'Smaragd' arbovitae as affected by controlled-release fertilizers. Fertilizer 1 (16-8-10) and fertilizer 2 (18-7-10) were prototype blends with different experimental polymer coatings. Fertilizer 3 was a blend of 18-5-8, which combined 100 percent resin-coated prills with a polymer coating. Fertilizer 4 was Osmocote Plus 15-9-12. Error bars about each mean are SE; 1 g = 0.0353 oz, 1 mS*cm^{-1} = 1 mmho*cm^{-1}.

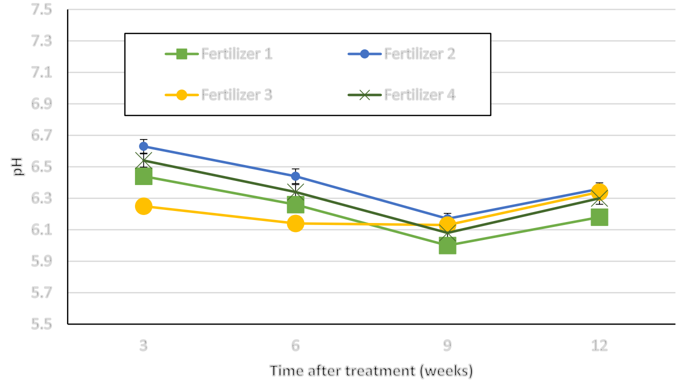

Figure 4. Leachate pH in 'Smaragd' arbovitae as affected by controlled-release fertilizers. Fertilizer 1 (16-8-10) and fertilizer 2 (18-7-10) were prototype blends with different experimental polymer coatings. Fertilizer 3 was a blend of 18-5-8, which combined 100 percent resin-coated prills with a polymer coating. Fertilizer 4 was Osmocote Plus 15-9-12. Error bars about each mean are SE; 1 g = 0.0353 oz, 1 mS*cm^{-1} = 1 mmho*cm^{-1}.

It was concluded that fertilizers 1 and 2 produced the highest shoot dry weight in Japanese spirea and arbovitae, with fertilizer 3 being equal to fertilizers 1 and 2 only in arbovitae. With Japanese spirea, fertilizers 1 and 2 were observed to produce a deeper green foliage and higher shoot dry weight when compared to fertilizers 3 and 4. Fertilizers 1 and 2 were prototype blends with experimental polymer coatings and, based on these data, have potential for use in Kentucky.

Fertilizer 3 resulted in the highest EC at the first pour-through and was the lowest (below 1.0 mS•cm^{-1}) by the third pour-through in both species. EC was higher as rate increased in both species. Rate also impacted shoot dry weight in both species. There was not incremental increase in Japanese spirea shoot dry weight between rates 2 and 3; however, arbovitae shoot dry weight increased with increasing rate.

Interestingly, mean leachate pH was similar for the two test plats at 2 to 3 weeks after treatment but at the last pour-through (week 12) the pH in arbovitae averaged 6.3 while pH of Japanese spirea averaged 7.5. Fertilizer had a significant impact on pH in arbovitae, especially in the first 9 weeks, but fertilizer 3 resulted in a lower pH at the first two pour-through dates for both species which corresponds to the highest release rate during the time period. The impact of fertilizer 3 on leachate pH was likely due to the release rate pattern but having a portion of the N supplied by urea could have had an impact. pH rise, which was probably due to the relatively high pH and moderate alkalinity of the irrigation water, was buffered somewhat by fertilizer treatment in both species as the highest pH was in control plants which received no fertilizer.

Significance to the Industry

New coating technologies and blends of controlled-release fertilizers (CRF) for specific release rates are being employed to customize fertility for specific environments and crops. Effect of three controlled-release blends of 8- to 9-month Osmocote (ICL Specialty Fertilizers, Dublin, OH) on leachate EC and pH and growth response of 'Double Play Pink' Japanese spirea and 'Smaragd' arbovitae were studied. Fertilizer 1 and fertilizer 2 were prototype blends with different experimental polymer coatings. Fertilizer 1 was a 16-8-10 +1.8 magnesium (Mg) + trace elements. Fertilizer 2 was a 18-7-10 +1.8 magnesium (Mg) + trace elements. Fertilizer 3 was Osmocote Blend 18-5-8 +1.1calcium (Ca) +1.4Mg +5.8S + trace elements, which combined 100 percent resin coated prills with E-max Release Technology™ polymer coating. Fertilizer 4 was commercially available Osmocote Plus 15-9-12 +1.3Mg +6 sulfur (S) + trace elements. Fertilizer 3 released its nutrients earlier in the 12-week study than the other three fertilizers and resulted in lower shoot dry weight in both species. The new polymer coating technologies show promise for delivering a predictable release rate and are appropriate for container production of these woody shrubs in Kentucky.

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The Effects of Bluemax®-coated Aluminum Sulfate on *Hydrangea macrophylla* Bloom Color and Tissue Analysis

Carey Grable, Joshua Knight, and Dewayne L. Ingram, Horticulture

Nature of Work

Hydrangea macrophylla is a popular landscape plant with the U.S. nursery and landscape market and is one of the industry's staple plants (Fulcher, 2013; Fulcher et al., 2016; Owen et.al., 2017). Consumers are particularly interested in varieties which rebloom. *Hydrangea* are usually grown in #1 and #3 containers. Growers typically try to produce *Hydrangea* with blue blooms, which are the most marketable plants. In order for *Hydrangea* to produce blue blooms, soil pH must be in the appropriate range and there must be aluminum available for the plant to uptake (Schreiber et al., 2010; Toyama-Kato et al., 2003). Research has shown a positive correlation between the amount of aluminum present in leaves and the amount of blue in blooms (Blom and Piott, 1992). Traditionally, an aluminum sulfate powder has been used as a topdress by nurseries to produce blue *Hydrangea*. These powders may have to be applied multiple times to keep soil pH down and aluminum levels up. Blue Max™ is a coated aluminum-sulfate product produced by ICL Specialty Fertilizers, Dublin, OH. which is made to increase levels of soil aluminum as well as lower soil pH while also having a longer release period than powders. The purpose of this study was to quantify this coated aluminum sulfate's longevity in container substrates and *Hydrangea* bloom color.

On 1 June 2016, *Hydrangea macrophylla* Let's Dance® 'Blue Jangles' and Let's Dance® 'Starlight' were transplanted from 1-L containers into #3 containers and were placed into a Quonset with 30 percent shade and overhead irrigation. The substrate used was 80 percent pine fines and 20 percent peat, amended with 4.8 kg·m-3 dolomitic limestone or 1.2 kg·m-3 dolomitic lime plus an equivalent amount of calcium and magnesium to match the high lime rate from calcium sulfate and magnesium sulfate. The containers were topdressed with two rates of coated aluminum sulfate (52 g and 78 g per #3 container) plus an untreated control rate of 0 g. Containers were also top dressed with 84 g of 8 to 9 month 15-9-12 Osmocote Plus and a pre-emergence herbicide, OH2. The pots were placed in 10 randomized blocks to help control for environmental factors. Electrical conductivity and pH were recorded at 2, 4, 8, and 12 weeks after planting. The plants were overwintered in an unheated Quonset structure covered with white poly. Microfoam thermal blankets and another layer of poly were also used internally to help augment protection during periods of

Figure 1. Color rating scale for *Hydrangea macrophylla* 'Blue Jangles'.

Figure 2. Color rating scale for *Hydrangea macrophylla* 'Starlight'.

extreme cold. A second application of Bluemax was made when the plants were placed in the overwintering structure on 18 November 2016. A final pour-through test was run on 26 April 2017 and a second application of 84 g of Osmocote was made. The number and color of blooms was recorded in June 2017. Ten to twelve mature leaves near the blooms were removed at this time from 9 replicate 'Blue Jangles' plants which had received the 4.8 kg·m3 lime rate and each of the three coated aluminum sulfate treatments and sent to ICL Testing Lab (Lincoln, NE) for determination of elemental content. Bloom color for 'Blue Jangles' was rated on a scale of 1 to 5, with 1 being pink and 5 being blue (Figure 1). "Starlight' blooms were rated on a 1 to 3 scale, pink to blue (Figure 2).

Results and Discussion

Using the pour-through leachate extraction procedure, EC and pH were recorded at 2, 4, 8, and 12 weeks after potting. The leachate EC ranged from over 3.0 mS•cm^{-1} after 2 weeks, to less than 1.0 mS•cm^{-1} after 10 weeks. After 8 weeks, EC was greater for incremental increases in Bluemax rate in both 'Blue Jangles' and 'Starlight.' After 10 weeks, there was little effect on EC due to Bluemax. Starlight leachate pH was lowered by increasing rates of Bluemax at 2 weeks in treatments with the low lime rate. 'Blue Jangles' leachate pH was lower at the 78 g rate in the low-lime plants but there was no difference between the 0 g and 52 g rate.

The presence of coated aluminum sulfate had an effect on the number and color of blooms with both cultivars (Table 1). The level of lime had no effect on number or color of blooms. The number of 'Starlight' blooms was lowered by the two aluminum sulfate rates, but the number of 'Blue Jangles' blooms was not affected. The bloom color with both cultivars was affected by treatment with the 52 g and 78 g producing more blue flowers.

Tissue analyses of nutrient content of 'Blue Jangles' grown at the high lime rate showed differences due to aluminum sulfate rate. Greater nitrogen, potassium, and boron leaf content was found in the higher aluminum sulfate rate over the lower rate and control. Aluminum, sulfur, and copper leaf content went up with higher rates of aluminum sulfate while calcium content went down with increasing aluminum sulfate rates. A high correlation (0.85) was found between leaf aluminum content and blue bloom color. This correlation was observed to be higher than found in previous studies (Blom and Piott, 1992). This positive correlation between the observed elemental leaf content and blue color showed the impact of coated aluminum sulfate on blue bloom color. The threshold for blue colored blooms in the current study was observed to be at or below the 52-g treatment of coated aluminum sulfate. Bloom color averaged a color rating of 3.9 for both the 52-g and 78-g rates of coated aluminum sulfate.

Significance to Industry

Growers wishing to increase the marketability of their *Hydrangea macrophylla* will often try to ensure blue blooms. Any product which can aide growers in doing this will be of value to the nursery industry. Bluemax shows a release of aluminum over time and the potential of producing blue blooms in container- grown *Hydrangea*.

Table 1. Bloom number and bloom color as affected by coated aluminum sulfate and lime for *Hydrangea macrophylla* 'Blue Jangles' and 'Starlight'.

Treatment	Bloom Number	Bloom Color[z]
'Blue Jangles'		
Aluminum Sulfate[y]		
0	14.0 a[x]	1.1 a
52 g	13.8 a	3.9 b
78 g	12.9 a	3.9 b
Lime		
1.2 kg·m^3	14.0 a	3.0 a
4.8 kg·m^3	13.2 a	3.0 a
'Starlight'		
Aluminum Sulfate		
0	21.0 a	1.0 a
52 g	8.5 b	2.0 b
78 g	8.8 b	2.0 b
Lime		
1.2 kg·m^3	12.6 a	1.7 a
4.8 kg·m^3	12.8 a	1.7 a

[z] Bloom color rating for 'Blue Jangles' was on a scale of 1 to 5 with 1 being pink and 5 being deep blue. 'Starlight' bloom color was rated on a 1 to 3 scale, from pink to blue.
[y] Coated aluminum sulfate; Bluemax™ a coated aluminum-sulfate product produced by ICL Specialty Fertilizers, Dublin, OH.
[x] Means in each column for each cultivar and treatment group with the same letter are not statistically different.

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Use of K-IBA as a Foliar Spray for Softwood Cutting Propagation

Tyson Gregory and Robert L. Geneve, Horticulture

Nature of the Work

Common softwood cutting propagation involves the application of auxin as indole-3-butyric acid (IBA) in talc or a quick dip to the basal end of the cutting. Alternatively, auxin can be applied as a foliar spray over the top of cuttings after they are stuck (McGuire and Sorenson, 1966). This method has become a viable alternative for commercial cutting propagation because it offers several advantages over traditional application methods. The major benefits of foliar auxin sprays are reduced labor costs and increased worker safety. Additionally, the auxin spray could be administered at potentially any time after sticking giving the producer increased flexibility in the production process. An auxin spray also avoids potential alcohol damage to the basal portion of cutting that traditional applications might exhibit.

This study utilized two species (*Hydrangea paniculata* 'Limelight' and *Rhus aromatica* 'Gro-Low') that were chosen based on their sensitivity to a foliar auxin treatment. The objective of this study was to determine the effects of auxin concentration and timing of application on the rooting of the two species.

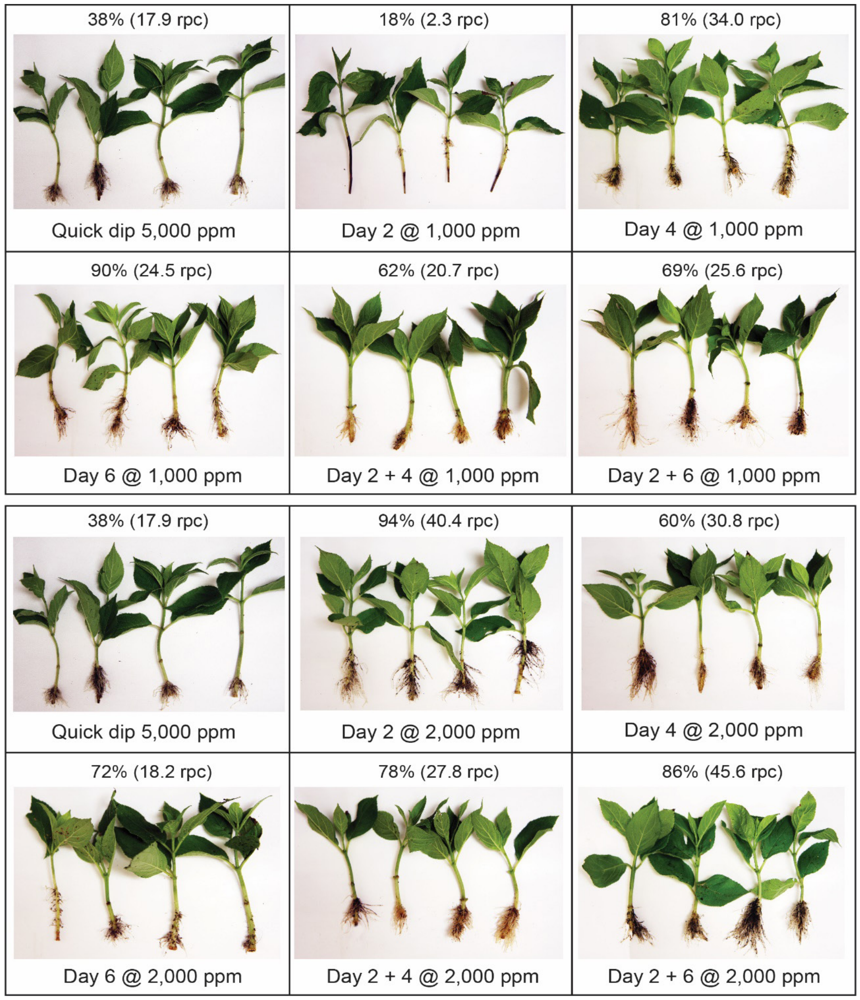

Figure 1. Rooting percentage and roots per cutting (rpc) in *Hydrangea paniculata* 'Limelight' cuttings treated with 1,000 or 2,000 ppm IBA foliar sprays at different times after sticking.

Materials and Methods

Cuttings of both species (*Hydrangea paniculata* 'Limelight' and *Rhus aromatica* 'Gro-Low') were sourced from Decker's Nursery, Groveport, OH. The cuttings were transported to the University of Kentucky horticulture greenhouse where they were prepared and stuck. Both species were prepared for treatment identically to the production in Decker's Nursery. *Hydrangea* cuttings were cut to an average length of four inches and the upper two sets of leaves were left intact. *Rhus* cuttings were processed to leave five nodes per cutting. More than 700 cuttings were prepared for each species and stuck into deep celled, nursery production 6-packs. The cuttings were divided into 11 treatment groups after preparation: IBA quick dip (5,000 ppm), single spray treatment the day after sticking (day two), on day 4 and day 6. Multiple spray applications were made on day 2 plus day 4 and day 2 plus day 6. K-IBA concentration for *Hydrangea* was 1,000 ppm and *Rhus* at 2,000 ppm. Following sticking, the cuttings were placed in a mist bed with bottom heat and a misting interval of 10 seconds every 10 minutes. The entire mist bed was covered in a single layer of shade cloth to reduce heat load throughout the day.

The flats were treated by spraying the cuttings in the morning with a hand sprayer until the leaves were saturated and slightly dripping. The K-IBA solution was allowed to completely dry on the leaves before misting was resumed. *Hydrangea* cuttings were evaluated 17 days after sticking, while *Rhus* cuttings were evaluated after 30 days. Cuttings were evaluated for roots per cutting and cutting quality was estimated on a scale of 0 to 5 where 0 was unrooted and 5 had numerous elongating roots. A subsample of rooted cuttings was transplanted to the greenhouse and evaluated after two months for branching and shoot length.

Results and Discussion

In *Hydrangea,* the foliar K-IBA application was more effective for rooting than a quick dip, except when treated with 1,000 ppm the day after sticking (Figure 1). The best rooting occurred with a treatment of 2,000 ppm the day after sticking with 94 percent rooting and an average of 40 roots per cutting. The remaining applications exhibited good rooting as well, but the applications of 1,000 ppm K-IBA performed better than applications of 2,000 ppm. *Hydrangea* responds well to foliar applications (Blythe et al., 2003) and the suggested concentration is between 500 and 750 ppm (Kroin, 2009). The efficacy of the auxin spray compared to a quick dip at similar concentrations is supported by Drahn (Drahn, 2007), working with several different cutting types. However, *Hydrangea* cuttings did not root well at the lower auxin concentration the day after sticking (18% rooting and 2.3 roots per cutting at 1,000 ppm). This indicates that while a lower concentration may be sufficient, the cuttings needed to fully acclimate to the misting environment to root without a higher auxin concentration. This may be partly explained by the delay in sticking following transport of the cuttings that could have led to lower foliar auxin absorption.

There were no significant differences in *Hydrangea* rooting when auxin application was delayed for up to six days after sticking (Figure 1). There was also no obvious additive or synergistic effect observed in rooting with multiple auxin sprays. From a practical standpoint, these data provide a window for initial auxin sprays where auxin remains effective for rooting and also indicates that there is no incentive for multiple foliar treatments in *Hydrangea* cuttings.

Rhus cuttings are difficult to root and often not responsive to auxin (Tipton, 1990). *Rhus* cuttings experienced poor rooting success across all treatments (< 10% rooting - data not shown), which was not unexpected. The treatments with 2,000 ppm K-IBA had marginally higher rooting success than the 1,000 ppm treatments. The quick dip treatment also had unsatisfactory rooting, even with a concentration of 5,000 ppm. However, there was no observable difference between the quick dip and spray suggesting that a foliar application could be successful with a higher auxin concentration. Additionally, cuttings with a higher leaf area may exhibit a higher response to the auxin spray (McGuire, J.J., 1967). Further trials would need to be conducted to assess this.

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Developing a Modified Hydroponic Stock Plant System for Redbud

Veronda Lewis, Sharon T. Kester, and Robert L. Geneve, Horticulture

Nature of the Work

Cutting propagation is a major propagation method for the nursery industry, but there is very little stock plant management compared with the floriculture and forestry industries. Stock management of tropical annuals for cutting production has become a very specialized practice with most production occurring outside the U.S. Its stock plant management is characterized by starting with initially clean disease-free clonal material that is produced in containers under strict nutritional management. For woody plants, a selected number of deciduous forestry trees have been clonally propagated by selecting juvenile starting material for stock plants and then managing stock plants using a modified hydroponic system to optimize stock plant nutrition. The forestry industry has moved into commercial clonal production for a number of difficult-to-root crop species including *Eucalyptus* and some conifers (Assis, 2011; Chinnaraj and Malimuthu, 2011). The industry has been very successful with this approach, propagating large quantities of rooted cuttings for planting-out each year. There are three basic stock plant management principles that have allowed for consistent (>90%) cutting success. These include initial selection of juvenile material (stump sprouts, lignotubers or tissue culture), managed stock plant nutrition using a modified hydroponic system, and consistent, timely removal of cuttings to keep cutting wood from maturing. This procedure has been termed "minicuttings" and they result in vigorous rooted cuttings that have better root systems compared to traditional cuttings (Cliffe, 2010). These stock plants produce vigorous managed shoot growth that yield cuttings that consistently root when taken as minicuttings.

The objective of this research was to develop a modified hydroponic system for minicutting production using eastern redbud (*Cercis canadensis*) as a model system. Eastern redbud makes a good model system because in addition to juvenile seedlings, eastern redbud cultivars available from tissue culture present a good juvenile stage starting material for a minicutting stock plant program. In addition, although eastern redbud is difficult to root from cuttings, it does show rooting potential during a brief window of time during the growing season.

Materials and Methods

Plant material: Juvenile eastern redbud plants were raised as seedlings. Mature clones were established as hedged stock blocks at the University of Kentucky research station.

Stock plant production system: Stock plant production systems were established for minicutting production in sand beds and

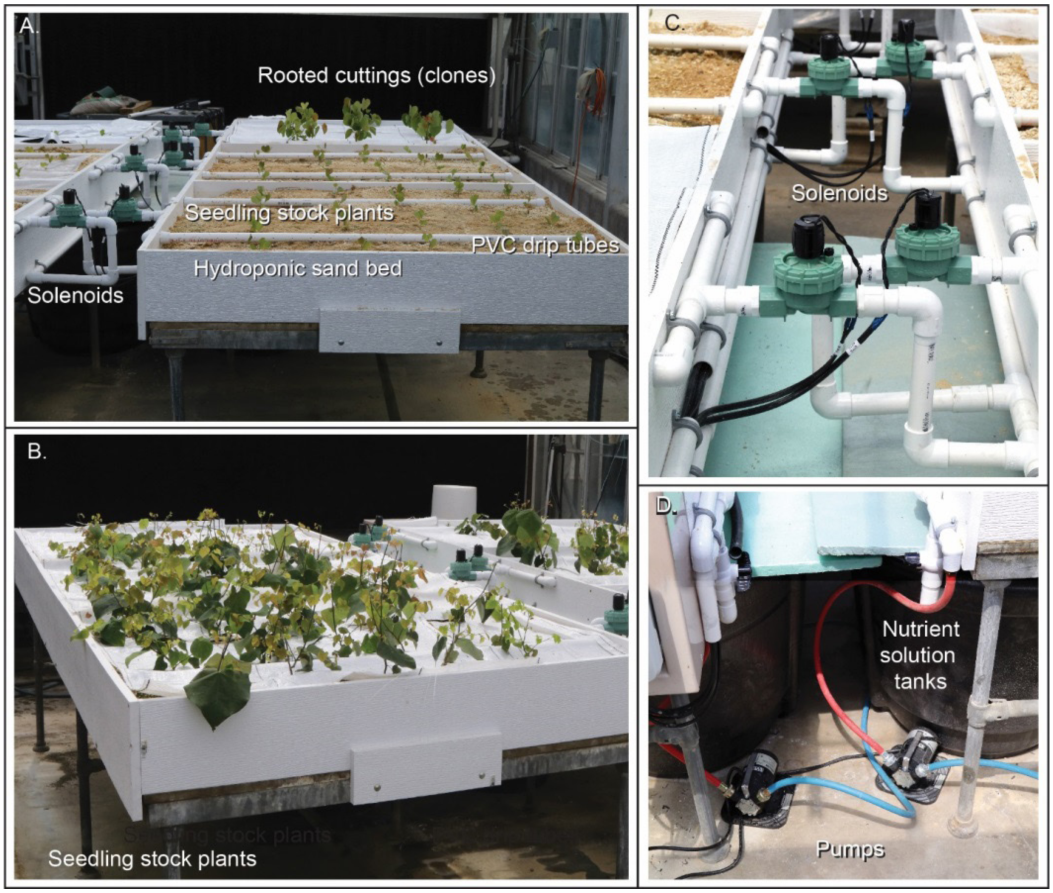

Figure 1. Sand bed production of stock plants. (A) Sand bed. (B) Stock plants after several rounds of hedging. (C and D) System for pumping nutrient solution to sand beds.

coir bags (Figure 1). Each were irrigated with a modified hydroponic nutrient solution using an automated timing system. Initial experiments compared full-strength with half-strength nutrient solution for stock plant growth. In addition, clonal plants purchased as grafted material were established in hedged stock blocks in field beds. Stock plants were pruned every three weeks two three nodes.

Cutting propagation: Terminal cuttings were rooted under mist. Cuttings were treated with IBA concentrations ranging from 0 to 15,000 ppm as a quick dip. Cuttings were evaluated for time to first root emergence, rooting percentage, number of roots per cutting.

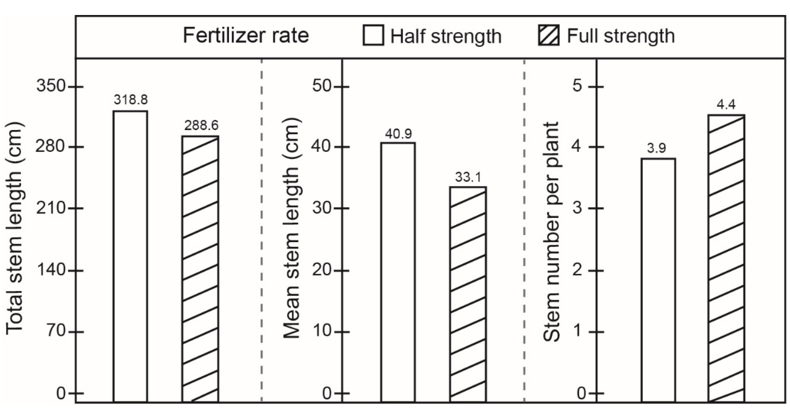

Figure 2. Impact of nutrient solution rate on greenhouse-grown stock plant development.

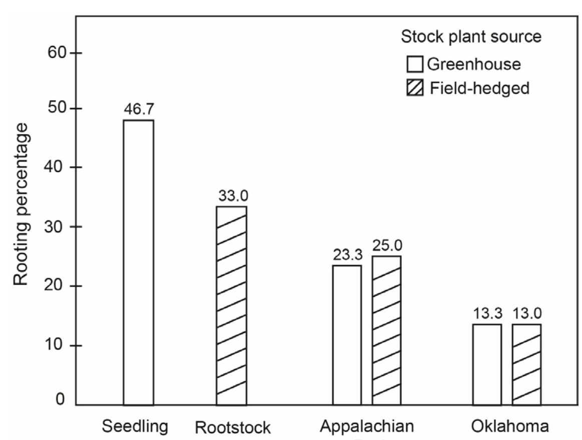

Figure 3. Rooting percentages for seedling and clonal redbud cuttings taken from greenhouse or field-managed stock plant plants.

Results and Discussion

Stock plants grew vigorously in the modified hydroponic sand beds. It was determined that plants responded equally well when irrigated at full- or half-strength nutrient solutions (Figure 2). Subsequently, all sand beds were moved to half-strength fertilizer solutions. Stock plants in sand beds have gone through four rounds of pruning and it appears that cuttings will be available every two to three weeks.

A preliminary dose response to auxin using seedlings or clonal cuttings from hedged stock plants indicated that cuttings responded to 10,000 and 15,000 ppm auxin as a quick dip. Rooting was very similar for cuttings taken from greenhouse- and field-grown stock plants (Figure 3). Seedling and rootstock cuttings were easier to root compared to cuttings from clonal plants. The highest rooting for clones was below 30 percent. Also, 'Oklahoma' cuttings consistently rooted at lower percentages than 'Appalachian Red.'

Acknowledgments

This research is supported by a grant from the Horticultural Research Institute and the IPPS-ER.

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Lagerstroemia fauriei 'Kiowa' Propagation by Hardwood Cutting

Zenaida Viloria, Winston Dunwell, Ginny Travis, and Dwight Wolfe, Horticulture

Nature of Work

Japanese crape myrtle, *Lagerstroemia fauriei* Koehne, is native to central and south Japan, and grows to reach 6 to 15m in height, unlike common crape myrtle (*L. indica* L.) , which is considered a medium to large (4-8m) size shrub. 'Kiowa,' 'Fantasy,' and 'Townhouse' crape myrtles are selected cultivars of *L. fauriei* available at the USA nursery industry. These cultivars are valuable not only as landscape plants but also as promising breeding progenitors due to their interesting traits such as: white canopy in full bloom, smooth cinnamon bark (Figure 1A), resistance to mildew and leaf spot fungus, and cold hardiness. Particularly, 'Kiowa' crape myrtle, a USDA selection, is characterized as top hardy in USDA hardiness zone 7b and root hardy to USDA zone 6 (Pooler and Dix, 1999). Cold hardiness in *L. fauriei* might be related with its stronger tendency to remain dormant for longer time in spring compared with *L. indica* (Pounders et al., 2010). A 'Kiowa' crape myrtle tree grown at the UKREC, Princeton, Kentucky (USDA zone 6), has survived with no major injuries several winters. Interestingly, the cold hardiness trait present in 'Kiowa' could extend its landscape use to regions with colder winter temperatures.

Unfortunately, 'Kiowa' crape myrtle is a hard-to-root cultivar. Just 10 percent of the cuttings rooted when commercial formulation of indole-3-butyric acid (IBA) was applied to juvenile softwood cuttings (Pooler and Dix, 1999). Conversely, 90 percent of semi-hardwood cuttings of Lagerstroemia 'Natchez,' a *L. indica x L. fauriei* hybrid, rooted with a basal quick dip in a solution that combined 1000ppm IBA + 500ppm naphthalene acetic acid (Blythe et al., 2003). A potassium salt IBA solution promoted rooting in seedless 'Xiangyun' crape myrtle softwood cuttings in two weeks (Wang et al., 2014), but as a foliar spray did not affect rooting significantly (Blythe et al., 2003). Other *Lagerstroemia* species and hybrids are easily propagated from softwood, semi-hardwood and hardwood cuttings treated with rooting hormones (Pooler, 2006; Pounders et al., 2013; Dirr, 1990). Auxin treatment in combination with wounding have improved rooting in hardwood cuttings of diverse species (De Silva et al., 2005; Blazich and Hinesley, 1994; Tsipouridis, 2005). Nurserymen need efficient and reliable protocols to propagate adult 'Kiowa' crape myrtle donor or mother plants. The main objective of this study was to evaluate a commercial rooting hormone and a basal wounding technique for their potential in propagating 'Kiowa' crape myrtle by using hardwood cuttings.

Materials and Methods

Hardwood branches were chosen from a single 'Kiowa' crape myrtle tree in early December 2016. Branches were sectioned to make 20-cm-long cuttings, with 1.0-1.5cm diameter. Cuttings were divided into two groups to apply wounding and non-wounding treatments. Cuttings were wounded by four longitudinal 2-cm cuts opposed to each other on the periphery of the basal end. Commercial hormone rooting powder (Hormodin® OHP, Inc.) at 0.1, 0.3, and 0.8 percent indole-3-butyric acid concentrations was applied by dipping about two to three cm of the cutting base in the powder. A control treatment (no rooting hormone) was also included for a total of 8 treatments. After rooting powder was applied, cuttings were individually inserted in 21-cell trays containing a mix of vermiculite, peat moss and perlite (2:2:1, v/v/v). Trays were placed on heat mats that kept the substrate temperature at 16°C. This experiment was carried out under greenhouse conditions with controlled temperature at 13°C. Substrate was hand-irrigated three times a week.

After 12 weeks, root number per cutting, root length (cm), rooted cutting percentage, shoot number, length (cm) and location, and cutting survival percentage were recorded. Data were

Figure 1. (A) 'Kiowa' crape myrtle tree in full bloom in mid-June, (B) rooted cuttings treated with 0.3 IBA, and (C) plants obtained via cutting after seven months of root initiation.

analyzed using generalized linear mixed model with the GLIMMIX procedure of SAS, (v.9.4; SAS Institute, Cary, NC) and modeling using the link functions as reported by Blythe (2012). The 8 treatments (4 hormone rates and 2 wounding treatments) were arranged in a factorial design, each treatment was allocated to the experimental units (10 cuttings per experimental unit) in a randomized block design with two blocks (replications).

Results and Discussion

Wounding did not significantly affect the adventitious root formation in 'Kiowa' crape myrtle hardwood cuttings, but commercial IBA rooting hormone powders (Hormodin® OHP, Inc.) improved rooting (Table 1). Among all treatments, the highest (0.8%) IBA concentration significantly enhanced the root number (0.89) and length (5.98 cm), and the quantity of rooted cuttings up to a maximum of 47.15 percent. It is been demonstrated that easy-to-root and difficult-to root genotypes differ in their ability to conjugate auxins to their inactive forms (Pacurar et al., 2014), which affects the free auxin concentration in the rooting zone. Additionally, differences between easy-to-root *Forsythia* and difficult-to-root *Syringa* were related with polar auxin transport. *Forsythia* internodes rooted whether the auxin was applied on either proximal or distal end, whereas *Syringa* showed differential polar auxin response with rooting occurring when hormone was applied at distal end. Basal auxin transport was present in both species (Marks et al., 2002). Accumulation of indole acetic acid in the rooting zone has two functions: induction of adventitious root formation in competent cells through controlling cell cycle and contribution to sink establishment in the rooting zone via involving sucrolytic enzymes that remodel microtubule and cell wall (Druege et al., 2016). Even though auxins play a crucial role in adventitious root formation, the ability of plants to develop *de novo* roots is a complex genetic trait regulated by the interaction of endogenous and environmental factors (Pacurar et al., 2014). It is likely that other physiological factors in 'Kiowa' crape myrtle and rooting conditions constrain rooting responses.

Basal application of rooting hormone significantly affected the axillary shoot development in 'Kiowa' crape myrtle hardwood cuttings (Figure 1B). Shorter shoots in lower numbers were observed as IBA rate was increased. Similarly, fewer shoots were observed at the low portion of the cuttings at 0.3 and 0.8 percent IBA. Nonetheless, shoots always grew actively without affecting further plant development. Auxins play important role in bud activity in intact plants and cuttings as well. Auxin-induced ethylene has been identified as a bud break inhibitor

Table 1. Adventitious root and shoot formation in *Lagerstroemia fauriei* 'Kiowa' hardwood cuttings 12 weeks after indole-3- butyric acid (Hormodin® OHP, Inc.) application.

AIB Concentration (%)	Root			Shoot		Shoot location		Survival (%)
	Number	Length (cm)	Rooted cutting (%)	Number	Length (cm)	Top	Bottom	
0	0.15b[1]	0.61b	15.63b	1.56a	14.66a	0.21a	1.34a	82.50a
0.1	0.27b	1.03b	21.21b	1.63a	16.18a	0.42a	1.21a	82.50a
0.3	0.41b	2.91b	24.33b	1.14ab	8.39b	0.57a	0.57b	92.50a
0.8	0.89a	5.98a	46.15a	0.69b	4.33b	0.26a	0.39b	97.50a

[1] Means with the same letter are not significantly different at the 0.05 probability level. Mean separation by least significant difference (LSD).

in rose cuttings (Sun and Bassuk, 1993). The inhibition extent might be related with the genotype and cutting physiological conditions among other factors. Blythe (2007; 2012) suggests that auxin effect on bud break and development was determined by auxin concentration and type. No symptoms of toxic levels of auxin were noticed. Moreover, high numbers of cuttings survived at the end of 12 weeks regardless the IBA rate, the highest survival rate was observed at 0.8 percent IBA.

Significance to the Industry

Commercial cutting propagation relies primarily on IBA and/or NAA as active ingredients of rooting hormones to produce new plants with strong root system in a short time. The use of commercial IBA hormone rooting powder and hardwood cuttings improved previous 'Kiowa' crape myrtle cutting propagation. Active growing plants, 1.22m height (Figure 1C), were produced seven months after rooting initiation. 'Kiowa' crape myrtle propagation protocol described here needs to be improved to make it efficient and profitable to nurserymen. It is convenient to evaluate other factors such as substrate, cutting type and seasonal effect.

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2017 Observations on Soil Moisture Monitoring Irrigation Control

Winston Dunwell, Zenaida Viloria, Daniel Becker, and Dwight Wolfe, Horticulture

Nature of Work

Vaccinium corymbosum L., highbush blueberries are a crop with excellent long-term profitability potential for Kentucky producers willing to invest the time, capital, and management necessary for establishing productive blueberry acreage. Berries have been a superstar of the U.S. produce industry since the 1990s, and U.S. demand for all berries continues strong. Kentucky direct farm marketers have realized the potential for marketing high-value crops like berries at farmers markets, on-farm markets and direct to restaurants and groceries (Woods, 2014). Out-of-state inquiries have shown a potential for Kentucky producers to tap into a wholesale market window for blueberries.

Figure 1. Echo-EC-5 moisture sensor, PlantPoint manual, nM50 wireless node.

Figure 2. nM50 node in overwintering house to send media moisture sensor readings to office.

Highbush blueberries have health benefits that have created a high demand for a crop frequently grown in Kentucky soils of higher pH than optimal. In higher pH soils iron and manganese needed by blueberries can be in a form unavailable to the plants leading to chlorotic foliage and weakened plants. Soils for blueberries must be well drained. Growing blueberries in high pH and wet poorly drained and aerated soils results in greater susceptibility to Phytophthora root rot. Strang et al. state that growers should manage irrigation to avoid long periods of saturated soils. Crop profitability hinges on having irrigation and good management of the irrigation particularly on marginal soils (Safley, 2012).

Blueberry fruit production of southern highbush blueberries in beds of milled pine bark about 15 cm deep has become a popular production system in Georgia and Florida. One of the primary limiting economic factors in this system is the cost of the growing substrate, which can exceed $10,000 US per ha (2.47 acres) for high density plantings where 75 percent of the area is covered with milled pine bark (Krewer, 2002). Can the pine bark be put into containers and plants grown in a system that avoids high pH and Phytophthora-infested soils?

Materials and Methods

November 29, 2016, the PlantPoint™ system was installed at the UKREC Horticulture! - Nursery Crops Research. The May 17, 2017, Potted Blueberry Container Study used two types of containers and four different types of media (Viloria, 2018)

Duke blueberry plants (2 year liner: 1 year in 7 gallon) will be used. Duke blueberry plants were transplanted into 25 gallon plastic and fabric containers in peat/pine bark/perlite mixes as substrates. They will be grown on a gravel bed. Pour-through Extraction will be done every 2 weeks to monitor fertilizer status (Dunwell, 2015 and Grable, 2012). The soil moisture monitoring irrigation control will be compared to time scheduled cyclic irrigation for plant growth, leachate, and future fruit production. PlantPoint™ soil moisture monitoring irrigation control will be evaluated in the first year for plant growth and long-term for volume of fruit production. Roots will be examined visually to determine root rot infection.

Nursery production of blueberry plants (1 year old liner: 1 year in 7 gallon) for sale to fruit growers and home gardeners will be transplanted to 15 gallon plastic containers with 100 percent pine bark substrate. Irrigation control systems will be used. The blueberries will be fertilized with Osmocote Plus 15-9-12, 12-14 month, at the manufacturer's medium rate for the container size.

Objectives of the study are: 1) to evaluate growth of Duke blueberry during nursery stage and fruit production using soil moisture monitoring irrigation control; 2) to evaluate container and substrate mixes for blueberry fruit production; and 3) to determine Phytophthora incidence in nursery blueberry production and blueberry fruit production.

Results

Decagon Corporation changed its name to METER Group following a merger with UMS AG in Munich Germany. The merger lead to PlantPoint™ being put on hold for re-evaluation of the project. Because of the hold, the system installed in November 2016 could not be expanded. Research related to sensor-controlled irrigation could not be completed for 2017 as planned. Media moisture was monitored over the course of the growing season and e-mail alerts based on two sensors were

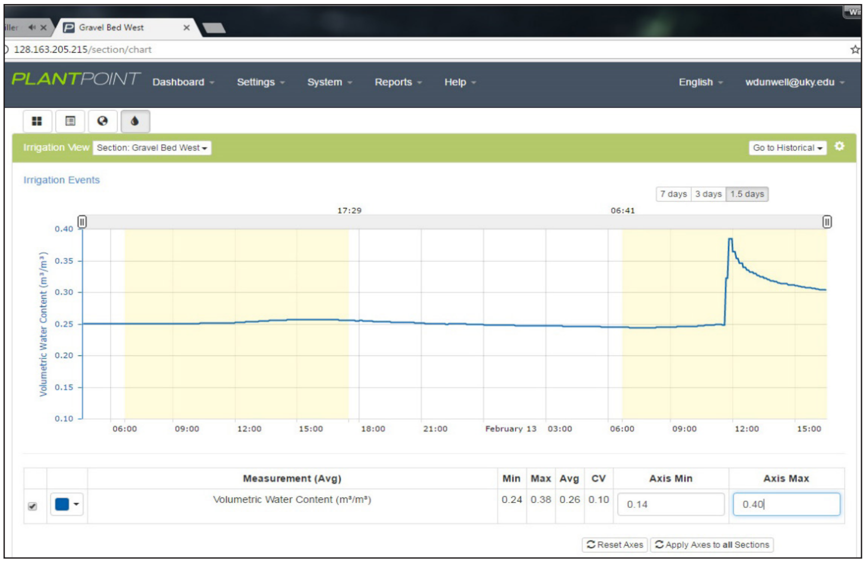

Figure 3. Office computer readout showing irrigation event.

Figure 4. Split wire loom (cover, conduit, wrap) for protection from rabbit damage.

used to ensure the moisture levels were maintained between 0.20 and 0.40 volumetric water content (VMC = water volume m3/ soil volume m3) with an average of 0.26. The initial minimum setting for triggering a water event was 0.14 VMC. Mayim, LLC (http://mayimllc.com/) is in the process of developing a wireless control node, under test by Dr. John Lea-Cox, University of Maryland, that will integrate with other monitoring nodes and sensors from METER Group, to replace the PlantPoint™ system. The Mayim, LLC software (Sensorweb) that supports all the field equipment is already commercially available.

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Carbon Footprint and Cost of Greenhouse-grown 4.5-inch Begonia Using Life Cycle Assessment

Dewayne L. Ingram and Joshua Knight, Horticulture Department, University of Kentucky; and Charlie R. Hall, Horticulture Department, Texas A&M University

Nature of Work

Production of annual bedding plants is the primary profit center for many greenhouse operations. However, decreasing profit margins for these crops require a continual increase in efficiency of these production and marketing systems (Hall, 2010). Life cycle assessment (LCA) is a tool used to analyze the production system components from cradle to grave or defined subsets of their life cycle.

Greenhouse gas emissions (GHG) and the subsequent carbon footprint (CF) have been reported for representative trees and shrubs produced in field operations and in container production systems (Hall and Ingram, 2014, 2015; Ingram, 2012, 2013; Ingram and Hall, 2013, 2014a, 2014b, 2015a, 2015b; Ingram, Hall and Knight, 2016, 2017a; Kendall and McPherson, 2012). Young foliage plant production systems in two distinct greenhouse types have also been compared using LCA (Ingram, Hall and Knight, 2017b). CF is expressed in global warming potential (GWP) for a 100-year period in units of kilograms of carbon dioxide equivalents (kg CO2e). Thus, our objective in this study was to study the environmental impact potentials and variable costs of finished plant greenhouse production in the northeastern region of the U.S. for finished annual color plants in 4.5-inch containers.

A production system/model for greenhouse production of 4.5-inch wax begonia (*Begonia x semperflorens-cultorum*) was based on grower interviews in the northeastern U.S. who provided information on input products, equipment use, heating and cooling requirements, water use, and labor hours for each operation or cultural practice. The system modeled consists of purchasing plugs in 288-count trays, transplanting them to 4.5-inch containers in 12-plant shuttle trays, and growing them for 8 weeks before marketing. General greenhouse operations, overhead, and energy use were calculated for an 8-week portion of a 50-week cropping year. The greenhouse was modeled as a gutter-connected, Dutch-style house with roof and side ventilation, horizontal circulating fans, bi-layer polycarbonate covering, high sidewalls, and no evaporative cooling, in the northeastern U.S.

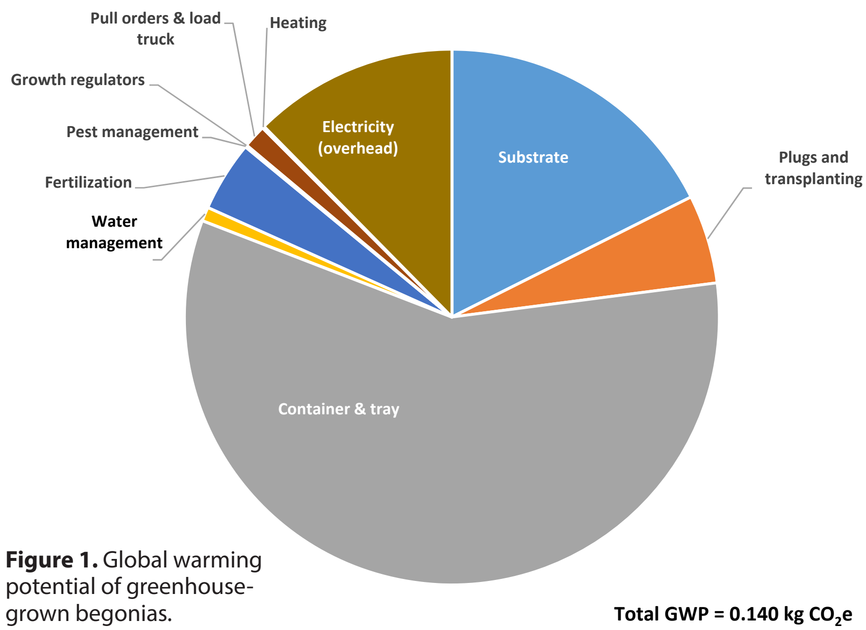

Figure 1. Global warming potential of greenhouse-grown begonias.

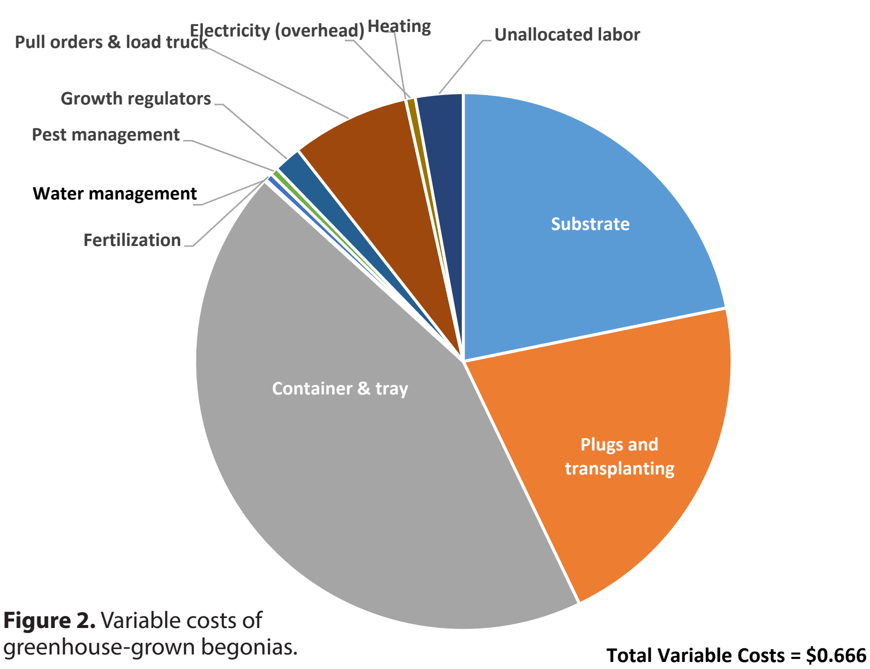

Figure 2. Variable costs of greenhouse-grown begonias.

It was assumed that 6.6 plants were produced on each square meter of a concrete floor and plants were irrigated using an overhead, traveling boom. Heating of the greenhouse would be required for 3 months and consume 16 ft^3 of natural gas per 1,000 ft^2. In addition to the electricity allocated to specific operations, such as water management, 0.047 kWh of unallocated electricity was assigned to each plant. In addition to the labor assigned to each operation, it was assumed that an additional 560 labor hours per 10,000 plants were needed but were not able to be allocated to specific operations.

Irrigation water would be pumped from a storage tank filled with roof-captured rainfall and supplemented from a well. Irrigation water would be continuously filtered and ozonated to supply 2 ppm ozone and require 36 kWh of electricity per 10,000 plants. Treatment of waste water would require 19 kWh of electricity per 10,000 plants and utilize a bacteria filter at a cost of $0.02 per 1,000 gallons. Fertilization would be provided with irrigation each week at 200 ppm N from a 14-14-14 water-soluble fertilizer with ammonium nitrate-based nitrogen sources.

Although labor does not contribute directly to a product's CF, it contributes significantly to product variable costs. The adverse effect wage rate as determined by the U.S. Department of Labor (2017) was used to set the hourly wage rate of $12.69. This rate represents the wage level that must be offered and paid to migrant workers by agricultural employers of nonimmigrant H-2A agricultural workers. Equipment costs per hour were representative of those reported in regional enterprise budgets for horticultural crops.

The study was conducted in accordance with LCA standards, including the International Organization for Standardization (ISO [Geneva, Switzerland], 2006) and PAS 2050 guidelines by BSI British Standards (2011). Input products, equipment use, and labor for each phase for the three production scenarios were inventoried. GHG were determined, converted to kilograms CO2e per functional unit and summed. Costs of inputs, equipment use and labor were determined for the model system. More production protocol details have been published in *HortScience* (Ingram, Hall, and Knight, 2017c).

Results and Discussion

A CF for a model production system for 4.5-inch wax begonia was calculated to be 0.140 kg CO2e from greenhouse gas emissions due to production protocols of the model system including use of input products, use of equipment and environmental controls (Figure 1). The total variable cost for this product was $0.666 (Figure 2). The container accounted for 30.8 percent of the CF and the 12-container shuttle tray contributed 26.6 percent, primarily due to the energy required to produce these products. These items also contributed 42.8 percent of variable costs. The substrate contributed 17.4 percent of CF and 21.3 percent of variable costs. Transplanting plugs from the #288 trays using a transplanter resulted in 5.3 percent of the CF (electric motors) and 20.6 percent of variable costs, labor in this instance.

Transferring plants from the potting area to the greenhouse floor accounted for 1 percent of CF and 2.4 percent of variable costs; pulling orders and loading trucks accounted for 1.4 percent of CFP but 7.0 percent of variable costs. Compared to distributing plants to the greenhouse floor, pulling orders required more labor because of the additional steps in locating the plants, grading as necessary, cleaning containers, etc.

Fertilization added 4.2 percent of CF but only 0.45 percent of variable costs. Pest management and application of growth regulators combined contributed only 0.13 percent of CF and 2.1 percent of variable costs.

Electricity to provide irrigation and treat the 30 percent runoff before discharge contributed less than 1 percent of CF and variable costs. Electricity not allocated to individual operations in the model accounted for 12.3 percent of CF and less than 1 percent of variable costs. Heating for 3 months of the 50 weeks of greenhouse production, when spread across the number of crop turnovers, had a very minor impact on CF and costs.

Significance to the Industry

Containers, shuttle trays, transplant/transplanting, and the substrate accounted for the greatest portion of CF and variable costs in this model system. Managers should evaluate the potential for possible savings in each of these inputs and process as they assess production protocol efficiencies. These analyses did not consider possible differences in market window, customer preferences, or anticipated selling price between the scenarios that managers must consider.

Although woody plants contribute to long-term carbon sequestration and make significant contributions to carbon dioxide remediation, herbaceous annual flowering plants such as begonia contribute to human health and well-being in other ways through their aesthetic value and ecosystem services such as reduced storm water runoff and improved air quality.

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Developing Protocols for Monarch Butterfly and Bee Conservation Plantings Using Kentucky-grown Milkweeds and Flowering Nectar Plants

Adam Baker and Daniel A. Potter, Entomology

Nature of Work

Populations of the monarch butterfly, an iconic, beloved species renowned for its long-distance migrations, are threatened by loss of wild milkweed (*Aclepias* species), its sole larval host plant, to the extent that habitat restoration is essential to the species' survival. This project aims to evaluate eight species of native milkweeds for suitability for monarch butterfly conservation plantings in Kentucky. We are investigating growth characteristics and suitability of different milkweeds for attracting and supporting monarchs, as well as bees, and developing protocols for establishing monarch butterfly habitat in gardens, parks, right-of-ways, and golf course naturalized roughs. We are promoting use of Kentucky-grown plants for conserving monarchs and other pollinators through extension and outreach activities.

Eight species of milkweeds including common (*A. syriaca*), swamp (*A. incarnata*), butterfly (*A. tuberosa*), whorled (*A. verticillata*), spider (*A. viridis*), showy (*A. speciosa)*, broad-leaf (*A.* latifolia), and narrow-leaf (*A. fascicularis*) were grown from seed and transplanted to replicated gardens (Figure 1) at the UK Arboretum/State Botanical Garden of Kentucky in early May 2016. Natural colonization by monarchs was evaluated biweekly for two growing seasons. Monarch larvae were reared on plants of each species to compare suitability for larval growth and development. In addition, we profiled growth characteristics of each milkweed species (height, tillering, flowering, pod formation) and evaluated their resistance to pests (thrips, aphids, milkweed bugs) and attractiveness to bees and other pollinators.

Seeds of common, swamp, and butterfly milkweed were purchased from suppliers and either hand sown or drill seeded into in plots prepared in mixed vegetation pastures by scalping, vertical mowing, or fraze mowing. Success of establishment was evaluated the following spring.

We are also investigating best methods for propagating milkweeds for sale by Kentucky growers. The eight species are being grown in the greenhouse under different fertilizer regimes and in different media.

Results and Discussion

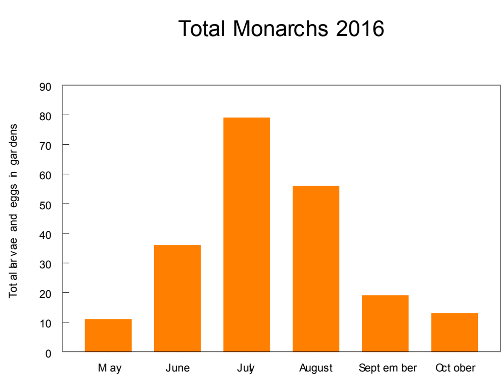
All eight species of milkweeds were suitable for larval growth, but the taller species (common, swamp, and showy milkweed) yielded the most monarchs (Table 1). Taller milkweed species may be easier for the butterflies to find. Common, showy, and narrow-leaf milkweeds spread from tillers making them the best-suited species for establishing large stands in natural areas (Table 1). Swamp and butterfly did not spread, so they are better suited for use in butterfly gardens. Butterfly, common, and narrow-leaf milkweeds were the most attractive species to bees, including honey bees and many native bee species. The small gardens at The Arboretum attracted and sustained monarchs throughout both growing seasons (Figure 2).

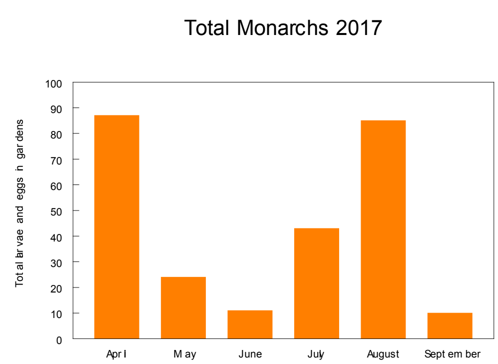
Based on our studies, and discussions with conservation biologists, we recommend the following for establishing milkweed stands in natural areas: (1) Sowing milkweed seed is unreliable; it is better to transplant seedlings. Purchase your plants locally, when possible, to ensure that they will do well in your climate. Ask the supplier for seedlings grown from more than one genotype to ensure they will be able to outcross and produce viable seeds in the field, and get 2-year plants when

Table 1. Comparison of eight milkweed species for yield of monarchs, tillering, height, and relative attractiveness to bees.

	Monarch eggs + larvae[a]		Tillers[b]	Plant height (cm)[c]		Bee
***Asclepias* spp.**	**2016**	**2017**	**2017**	**2016**	**2017**	**attractiveness[d]**
A. incarnata	15.2 ± 3.0 a	7.8 ± 0.8 ab	0	91 ± 1.5 a	109 ± 7.0 bc	Moderate
A. syriaca	8.0 ± 0.8 a	12.6 ± 3.4 a	1	89 ± 2.1 a	169 ± 9.9 a	High
A. speciosa	11.2 ± 1.7 a	16.8 ± 6.3 a	6	79 ± 3.6 b	138 ± 6.1 ab	Low
A. viridis	1.0 ± 0.3 c	1.4 ± 0.5 c	0	33 ± 1.8 e	47 ± 7.0 e	Low
A. tuberosa	2.0 ± 1.3 bc	5.4 ± 1.7 b	0.2	51 ± 1.6 c	73 ± 7.5 de	High
A. verticillata	1.2 ± 0.6 c	0.0 ± 0.0 d	15	53 ± 2.1 c	77 ± 19.5	Moderate
A. fascicularis	3.0 ± 0.7 b	6.6 ± 1.1 ab	103	82 ± 2.6 b	105 ± 16.0 cd	High
A. latifolia	1.0 ± 0.4 c	1.4 ± .07 cd	0.5	43 ± 2.0 d	60 ±5.5 e	Low

[a] Monarch larvae and eggs; 2016: $F_{7,28} = 14.5$, $P < 0.001$; 2017: $F_{7,28} = 14.5$, $P < 0.001$
[b] Mean height; 2016: $F_{7,28} = 101$, $P < 0.001$; 2017: $F_{7,28} = 14.2$, $P < 0.001$. Within columns, means followed by the same letter are not statistically different.
[c] Mean no. tillers produced per plot
[d] Based on two 2-minute bee counts during peak bloom; low = < 5, moderate = 5-10, high = > 10 bees





available. (2) Use milkweed species that produce tillers to fill in natural areas. (3) scalp down competing vegetation, plant in spring, and water seedlings for best establishment. (4) Mow in autumn after milkweed senesces.

For smaller butterfly gardens, we recommend using swamp milkweed because it is highly attractive to monarchs, and is non-tillering and will "stay put" where planted. Butterfly milkweed can add color, and will sustain some monarchs, but is probably better at attracting bees. In a related survey of 22 existing Monarch Waystations we found more monarchs in gardens located in rural and periurban sites than in urban ones. Gardens in which the milkweeds were set off by mulch and easily accessible to incoming butterflies had the highest monarch populations. Include a variety of flowering plants that offer season long nectar resources for migrating butterflies.

Our studies indicate that western flower thrips are the main pests of milkweed in greenhouse production. We are seeing significant differences in resistance among different milkweed species. That work will continue in 2018.

We have published an article about this research in Greenhouse Product News, and the project was featured in several other regional and national trade journals. The work was presented in talks at the Cincinnati Zoo, the North Carolina Arboretum, the Tri-State Green Industry Conference, and the KNLA winter conference, and at major scientific meetings.

Significance to the Industry

Providing plants for monarch butterfly conservation offers marketing opportunities for Kentucky growers, garden centers, and landscapers. This research is providing new information on which milkweed species are best suited for use in Kentucky and throughout the eastern USA, and how best to produce and establish them. It will promote the use of 'Kentucky Proud' regionally specific bio-types of milkweed and nectar plants,

Figure 1. Monarch butterfly laying egg on milkweed.(Photo credit: Beverly James)

Figure 2. One of the five research gardens with eight milkweed species at the UK Arboretum. Note variation in height and form of the different milkweed species.

Figure 3. A carpenter bee visits swamp milkweed. Different milkweeds attract different percentages of honey bees, bumble bees, and other native bees.

Figure 4. Monarch butterfly larva feeding on milkweed in the gardens.

and encourage the use of milkweeds that are best suited for monarchs and other pollinators.

Acknowledgments

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Assessing and Promoting the Value of Woody Ornamental Plants for Pollinator-friendly Landscapes and Urban Bee Conservation

Bernadette M. Mach and Daniel A. Potter, Entomology

Nature of Work

Maintaining bee-friendly habitat and food resources in cities and suburbs can help conserve bees' vital pollination services to gardens, ornamental landscapes, and native plants in fragments of semi-natural habitat. With bee populations imperiled by habitat loss, diseases, parasites, and other stresses one of the few ways in which citizens can help is by cultivating bee-friendly landscapes that provide food resources for bees in the form of nectar and pollen. While there are many lists of "bee-friendly" plants available, such lists tend to lack detail, omit many good plants, and are almost invariably based on anecdotal evidence rather than on empirical data.

With this project, we aimed to provide data-based plant recommendations for bee-friendly landscapes by documenting bee assemblages (types of bees, bee species richness and diversity) associated with regionally adapted species of flowering woody plants. To further our understanding of the value of these plants for bee conservation, we also investigated the nutritional quality of native and non-native woody plants. Using a subset of plants sampled in 2015-2016, we collected pollen and nectar to determine their nutritional content (carbohydrates, fats, protein). These data will enhance our understanding of the nutritional value of native and non-native woody plants as well as provide insight as to what nutritional cues may influence bee attractiveness and assemblages. Publicizing this work will help to spur sales and usage of Kentucky-grown plant materials, benefiting wholesale and retail nursery suppliers, garden centers, and landscapers.

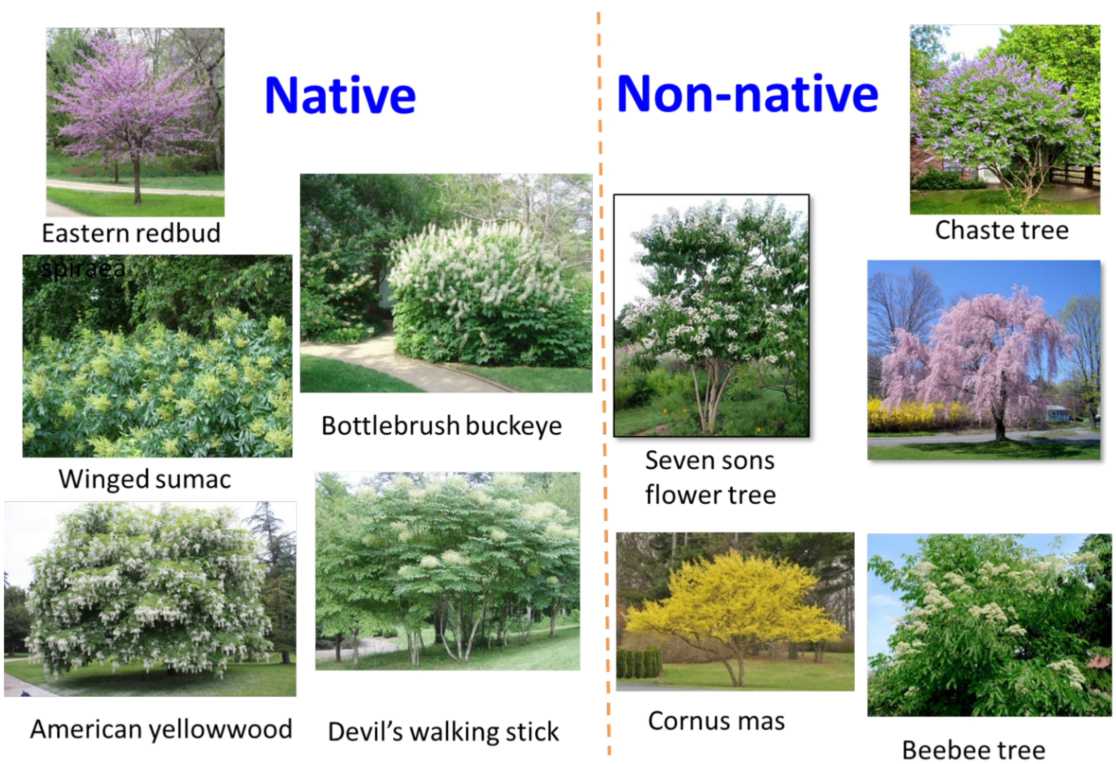

Figure 1. Both native and non-native trees can provide good resources for bees. These are some of many relatively pest free plants that our study showed to be "bee-friendly".

Figure 2. Examples of shrubs that are both bee-friendly and relatively pest-free.

Results and Discussion

To date, we have sampled 78 flowering woody plant species and identified approximately 12,000 bees. Results indicate that native and non-native species do not differ significantly in bee genus diversity, abundance, or attractiveness. Our data show that different flowering woody plants attract unique bee assemblages, regardless of whether they are native or non-native. Some species (e.g. flowering crabapple, blue/China holly, eastern redbud, and chaste tree) attract diverse assemblages of bees whereas others (e.g. linden, and mockorange) attract fewer, sometimes specialist species. In addition, some plants showed high site-to-site variation in their bee assemblages, which indicates that there are other factors that we did not measure, such as proximity to appropriate nesting sites, that may be at play.

We compiled rankings of bee-attractive flowering woody plants into a handout (supplemental material) hosted by the Horticultural Research Institute's growwise.org website in order to publicize the results of this study (http://growwise.org/wp-content/uploads/2017/02/ HRI-Pollinator-BeePlantLists-February2017.pdf). For the nutritional analysis objective, we successfully collected nectar and pollen from twelve species of highly bee-attractive flowering woody plants and will be completing the nutritional analysis this winter.

Significance to the Industry

Our data will help promote interest in and sales of Kentucky-grown plant materials to a citizenry increasingly interested in pollinator conservation. Such information will benefit nursery growers, retailers, landscapers, and other small business owners in Kentucky and elsewhere. By providing data-based plant recommendations, encouraging planting of diverse flowering ornamentals, and making it easy to select plants that will provide season-long resources, our work will help create more bee-friendly urban landscapes.

Uptake and Dissipation of Neonicotinoid Residues in Nectar and Foliage of Systemically Treated Woody Landscape Plants

Bernadette M. Mach and Daniel A. Potter, Entomology; and Svetlana Bondarenko, Valent USA

Nature of Work, Results, and Significance to Industry

Systemic neonicotinoid insecticides are versatile tools for managing insect pests, including invasive species, of trees and shrubs, but guidelines are needed to help land care professionals and homeowners use them without harming bees and other pollinators. We measured uptake and dissipation of soil-applied imidacloprid and dinotefuran in nectar and leaves of two woody plant species, a broadleaf evergreen tree (*Ilex × attenuata*) and a deciduous shrub (*Clethra alnifolia*) to assess concentrations to which pollinators and pests might be exposed in landscape settings. Three application timings, autumn (post-bloom), spring (pre-bloom), or summer (early post-bloom), were evaluated to see if taking advantage of differences in the neonicotinoids' systemic mobility and persistence might enable pest control while minimizing transference into nectar. Nectar and tissue samples were collected from in-ground plants and analyzed for residues by HPLC–MS/MS in two successive years.

Concentrations found in nectar following autumn or spring applications ranged from 166–515 ng/g for imidacloprid, and from 70–1235 ng/g for dinotefuran, depending on plant and timing. These residues exceed concentrations shown to have adverse effects on individual and colony-level traits of bees. Summer, post-bloom application mitigated concentrations of imidacloprid (8–31 ng/g), but not dinotefuran (235–1191 ng/g), in nectar. Our data suggest that dinotefuran may be more persistent than is generally believed.

Our results indicate that residues in nectar are likely to intoxicate individual pollinators foraging exclusively on treated woody plants. Therefore, a recommendation for integrating pest and pollinator management is to avoid their use on bee–attractive trees and shrubs unless there is no other way to prevent significant pest damage to such plants. Future work is needed to define the percentage of floral resources that systemically–treated plants represent in urban landscapes. Without such data, it is difficult to draw conclusions about the impact of these treatments on pollinator health at the landscape level.

A full report of this work is published in the scientific journal *Environmental Chemistry and Toxicology* (http://onlinelibrary.wiley.com/doi/10.1002/etc.4021/full). Contact dapotter@uky.edu if you would like a reprint.

Strengths and Limitations of *Bacillus thuringiensis galleriae* for Managing Japanese Beetles (*Popillia japonica*) in Urban Landscapes

Lindsey Wallis, Carl Redmond, and Daniel A. Potter, Entomology

Nature of Work

Landscape managers and homeowners need reduced-risk insecticides for managing pests of trees, shrubs, and lawns, particularly ones that do not harm bees and other pollinators. *Bacillus thuringiensis galleriae* (Btg), a Coleoptera-active strain, is a new microbial organic insecticide marketed for control of adults and larvae of Japanese beetle (*Popillia japonica*) and certain other beetle pests. Btg is currently sold under the trade names beetleGONE!® (Phyllom BioProducts, Oakland, CA) and beetleJUStm (Gardens Alive!; Lawrenceburg, IN). We evaluated field-aged spray residues of Btg for protecting linden (*Tillia* sp.), a preferred host plant, from Japanese beetle defoliation. We also tested for potential non-target effects on monarch butterfly (*Danaus plexippus*) larvae on milkweed and determined if Btg, applied as a foliar spray, has activity on aphids and lace bugs (Figure 1). Finally, we evaluated efficacy against Japanese beetle grubs in turfgrass, using both preventive and curative applications applied in early August, around the time of egg hatch, and in September against early third instars, respectively.

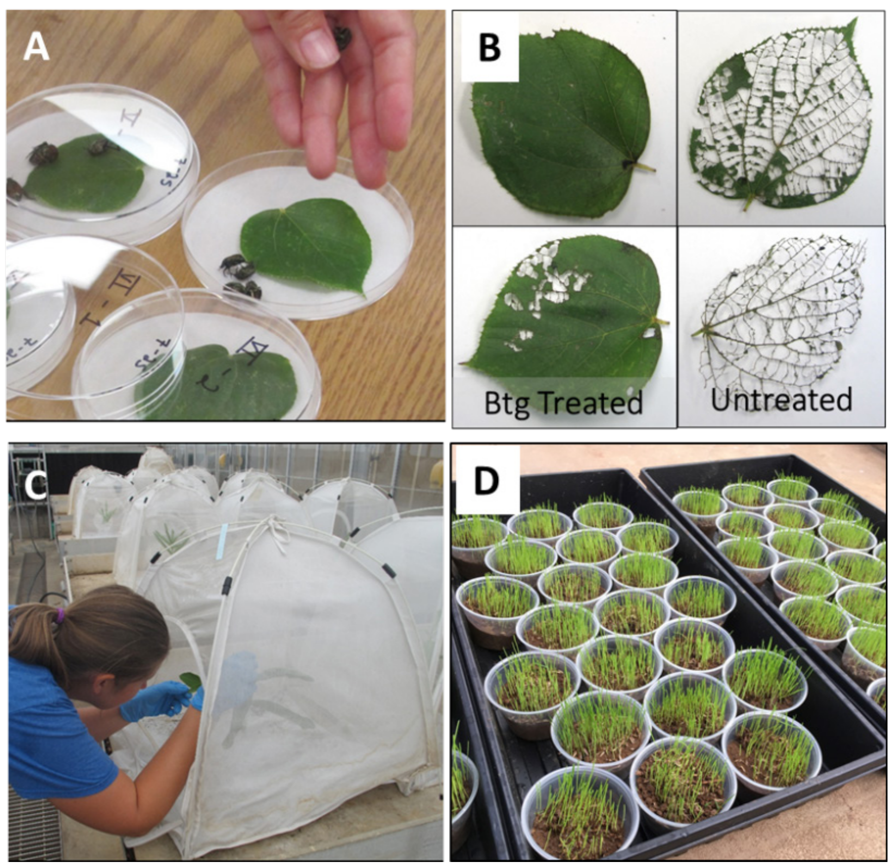

Figure 1. (A) Japanese beetle feeding assay with pre-sprayed linden leaves with different-aged residues. (B) Contrast in feeding damage after 24 hours. (C) Setting up the monarch caterpillar assay on Btg-sprayed milkweed in greenhouse. (D) Evaluating Btg activity against grubs in greenhouse-grown grass lacking thatch.

Results and Discussion

Btg was sprayed on linden shoots in the field, with residues allowed to weather for varying intervals up to 14 days. The shoots were then harvested and the leaves were challenged in petri dishes with Japanese beetle adults (Figure 1A). Btg spray residues significantly reduced Japanese beetle feeding on linden for at least 2 weeks after treatment (Figure 1B). However, it also caused over 98 percent mortality of monarch larvae feeding on Btg-treated milkweed (Figure 1C). The later result, confirmed in separate trials with beetleGONE and beetleJUS, means that Btg's action against caterpillars (Lepidoptera) makes it unsuitable for managing Japanese beetles in butterfly gardens.

In other trials, Btg showed no activity against cowpea aphid (*Aphis craccivora*) or hawthorn lace bug (*Corythucha cydoniae*), confirming that the products' activity against monarch butterfly larvae results from the Bt toxins as opposed to presence of a broad-spectrum contaminant in the formulations.

Preventive or curative application of a granular formulation of Btg (grubGONE!; Phyllom BioProducts) failed to significantly control of Japanese beetle grubs in turf field plots. To determine if its failure to control grubs resulted from lack of activity, or possibly failure to penetrate thatch and reach the target, we ran another trial in the greenhouse with recently germinated grass lacking thatch (Figure 1D). In that "best case scenario" trial, a liquid formulation of Btg caused significant mortality of third instar grubs but the level of control was only 46 percent.

This study indicates that foliar sprays of Btg at either the low or high label rates should give up to 14 days' residual protection from Japanese beetle defoliation. It appears to be an effective organic alternative for managing Japanese beetle adults. However, because of its crossover activity against caterpillars, Btg should not be used on plants in butterfly gardens. Our trials indicate that Btg is a weak performer against white grubs in turf. For white grubs, turf managers can use chlorantraniliprole (Acelepryn, Syngenta) which, if applied any time from early May to mid-July, will provide consistent preventive control of grubs with very low hazard to bees.

Significance to the Industry

Landscape managers and homeowners need reduced-risk, bee-friendly insecticides for managing pests of trees, shrubs, and lawns. *Bacillus thuringiensis galleriae* (Btg), a new organic insecticide, provided significant control of Japanese beetle adults as a foliar spray. However, it also showed high toxicity to monarch butterfly larvae. Btg seems to be a good fit for managing Japanese beetle adults in the urban landscape except around butterfly or pollinator gardens. Based on our trials, Btg appears to be a weak performer against white grubs in turf.

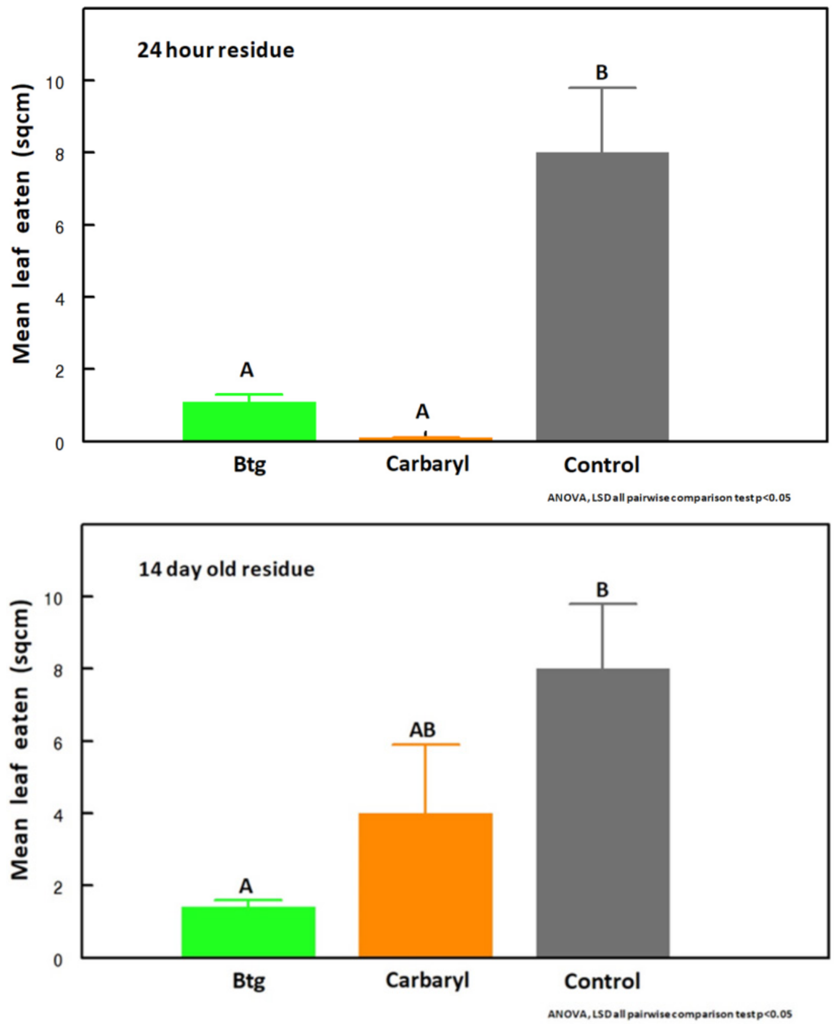

Figure 2. Results from JB adult feeding trials with 1 and 14 day old residues on linden.

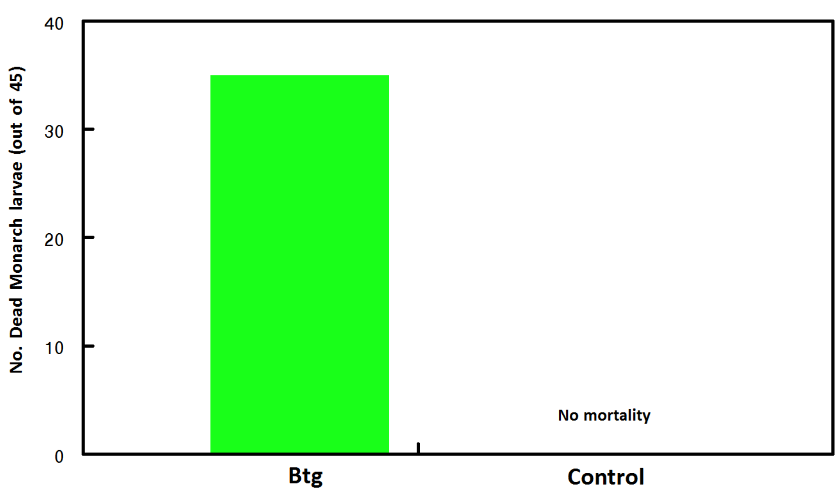

Figure 3. Mortality of monarch larvae on treated milkweed in greenhouse trial 1.

Chlorantraniliprole (Acelepryn®): Reduced-risk Insecticide for Controlling Insect Pests of Woody Ornamentals with Low Hazard to Bees

Carl T. Redmond and Daniel A. Potter, Entomology

Nature of Work, Results, and Significance to Industry

Landscape professionals need target-selective insecticides for managing insect pests on flowering woody ornamentals that may be visited by bees and other insect pollinators. Chlorantraniliprole, the first anthranilic diamide insecticide registered for use in urban landscapes, selectively targets the receptors which regulate the flow of calcium to control muscle contraction in caterpillars, plant-feeding beetles, and certain other phytophagous insects. Designated a reduced risk pesticide by the US EPA, it has a favorable toxicological and environmental profile including very low toxicity to bees and most types of predatory and parasitic insects that contribute to pest suppression. Chlorantraniliprole has become a mainstay for managing turfgrass pests but little has been published concerning its performance against pests of woody ornamentals. We evaluated it against pests spanning five different orders: adult Japanese beetles, evergreen bagworm, eastern tent caterpillar, bristly roseslug sawfly, hawthorn lace bug, oleander aphid, boxwood psyllid, oak lecanium scale (crawlers), and boxwood leafminer, using real-world exposure scenarios. Chlorantraniliprole's efficacy, speed of control, and residual activity as a foliar spray for the leaf-chewing pests was as good, or better than, that required by industry standards, but sprays were ineffective against the sucking pests (lace bugs, aphids, scales). Basal soil drenches in autumn or spring failed to systemically control boxwood psyllids or leafminers, but autumn drenches did suppress roseslug damage and Japanese beetle feeding the following year. This study indicates that chlorantraniliprole can be an effective component of integrated pest and pollinator management programs on woody ornamentals.

A full report of this work was published in the November 2017 issue of the scientific journal *Arboriculture & Urban Forestry*. To request a reprint, contact dapotter@uky.edu

Seasonal Emergence of Invasive Ambrosia Beetles in Western Kentucky in 2017

Zenaida Viloria, Ginny Travis, and Winston Dunwell, Horticulture; and Raul Villanueva, Entomology

Nature of Work

Ambrosia beetles bore sapwood and inoculate the galleries with fungi, which are collectively named ambrosia fungi. These fungi are derived from plant pathogens in the ascomycete group identified as ophiostomatoid fungi (Farrell et al., 2001). Ambrosial fungus garden is the food source for ambrosia beetles and larvae. *Xylosandrus crassiusculus* (granulate ambrosia beetle, GAB) and *X. germanus* (black stem borer, BSB) are considered the most destructive insect pests to the nursery crop industry. Ambrosia beetles usually mass attack nursery crops in spring, causing important loss due to the negative effect on the plant growth, aesthetic, economic value and unmarketable tree quality (Ranger et al., 2016). According to the field and container nursery growers of southeastern USA, GAB was ranked third as a key pest, 18 percent nursery growers identified it as prevalent and difficult to control (Fulcher et al., 2009). In Tennessee, *Cnestus mutilatus* (camphor shot borer, CSB) was found widely distributed and considered a new pest for nursery crops with unknown magnitude of damage (Oliver et al., 2012). Camphor shot borer was first reported from Kentucky in 2013, although a single specimen was found in Whitley County, it was believed it would be everywhere in the state due to its widespread in the neighboring states (Leavengood, 2013). The main objective of this study was to determine the phenology of the most abundant invasive ambrosia beetles in Western Kentucky.

Materials and Methods

Double bottle Baker traps were baited with ultra-high release ethanol (Contech Enterprises Inc. Canada). The ethanol pouch was attached to the upper bottle, and set over 1m above the ground. The catching bottle contained approximately 150mL commercial antifreeze to collect and kill insects. Four traps per location were set at the edge of the woods surrounding nursery stocks and orchards, and inside the orchards and nursery stocks. Traps were deployed in Calloway, Caldwell, Graves, and Todd Counties, in Western Kentucky in March 2017. Catching bottles were replaced weekly during March and April, and biweekly thereafter until early August 2017. In the laboratory, after filtering and rinsing each bottle content, ambrosia beetles were grouped and tallied under a dissecting stereoscope. Total number of beetles per trap per week was recorded.

Results and Discussion

The most common and numerous ambrosia species identified were GAB, BSB, CSB, and *Xyleborinus saxesenii* (fruit-tree pinhole borer, PHFB). These species are identified as invasive species. Invasive ambrosia beetles once established in new habitats surpass the populations of native species because their natural enemies are not present in the new ecological niches (Miller and Rabaglia, 2009; Helm, 2015; Werle et al., 2015; Gandhi et al., 2010).

Granulate ambrosia beetle populations started to increase the last week of March to reach the highest population peaks in April in the four counties (Figure 1A). In Todd County, the highest GAB population (768 beetles/week) was captured the third week of April, thereafter the number decreased abruptly. The second largest population was recorded in Graves County the second week of April. In Caldwell and Calloway Counties, the maximum populations (141 and 182 beetles/week, respectively) occurred the first week of April. Low captures occurred in apple and peach orchards, which might be a consequence of pesticide programs that included frequent insecticide sprays for the control of other pests (aphids, spider mites, fruit caterpillars, etc).

Camphor shot borer was the second most abundant invasive ambrosia beetle. The largest captures of CSB were recorded the second and third weeks of April, with the highest counts in Graves and Todd Counties (Figure 1B). Populations decreased considerably the last week of April in all counties. The highest numbers of CSB were captured in Calloway County in May and June. In chestnut nurseries, ambrosia beetle population peaks in spring and fall coincided with the time of attacks and tree damage (Oliver and Mannion, 2001). Spring ambrosia beetle attacks to nursery, landscape, and fruit trees have been reported in Western Kentucky lately. In 2017, we identified GAB as responsible for a mass attack to 'October Glory' maple in a nursery. Few CSB were also found in the galleries of infested trees. These two species were also identified attacking nursery apple trees in Jackson County, and 5 to 7mm diameter red bud branches from a home garden.

Regarding BSB, low populations were recorded from the four counties for short a time in the growing season (Figure 1C). Black stem borer started to emerge in March in Graves and Todd Counties, and no more BSB was found after July 7th in Calloway, Caldwell, and Todd Counties. In Caldwell, BSB was found from early April to mid-May, whereas in Calloway, the BSB was captured until early July. Low counts of BSB have been recorded previously in the southeastern USA (Miller and Rabaglia, 2009; Oliver and Mannion, 2001; Werle et al., 20115), but larger populations have been reported from northern states such as Ohio (Reding et al., 2011, 2015) and New York (Agnello et al., 2017), which might be related to its adaptability to high altitudes and cool climates (Reding et al., 2011).

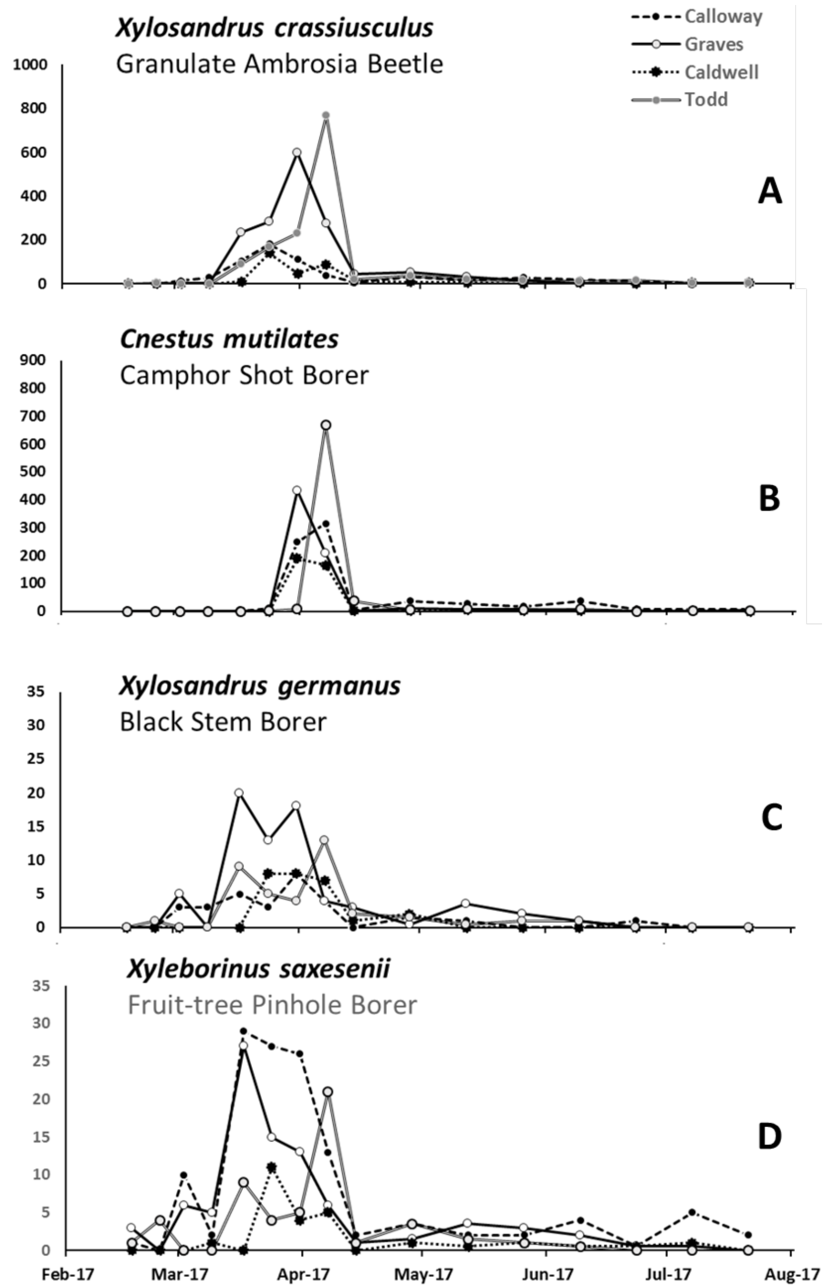

Figure 1. Seasonal captures of (A) *Xylosandrus crassiusculus,* (B) *Cnestus mutilates,* (C) *Xylosandrus germanus,* and (D) *Xyleborinus saxesenii* in Western Kentucky in 2017.

Fruit-tree pinhole borer reached the highest population in April, but its presence was detected during the entire growing season. Highest populations of FTPB were recorded in Calloway and Graves Counties from late March to the third week of April, with a maximum of 29 beetles/trap/week (Figure 1D). In Todd and Caldwell County, the FTPB population showed a single peak, with 21 and 11 beetles/trap/week, respectively. After the end of April the populations of FTPB were low in all four counties. High PHFB populations have been reported in avocado (Carrillo et al., 2012) and stressed black walnut (Reed et al., 2015). Despite the high population of PHFB in nursery crops, the attack number is low and non-significant (Oliver and Mannion, 2001; Reding et al., 2011).

Significance to the Industry

Granulate ambrosia beetle and camphor shot borer were found in large numbers in Western Kentucky in early spring. Ambrosia beetle attacks were identified in nursery and landscape plants. Regrettably, nothing can be done to recover infested plants, especially those that are grown in the nursery crop industry. Knowing the seasonal flight of ambrosia beetles is the first step to managing these pests; monitoring provides information to opportunely schedule preventive application of pyrethroids and thus increase the insecticide spray efficiency. Other more effective management strategies need to be evaluated to avoid ambrosia beetle attacks on nursery or fruit plants, such as reduction of biotic and abiotic stresses, and protection of plants with insecticide coated nets.

Acknowledgments

We thank the Nursery Crop Farmers of Western Kentucky for providing us access to their farms to conduct these studies. This study was possible thanks to the support provided by the Southern Region IPM-USDA/NIFA.

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2017 Annual Bedding Plant Evaluation in Nine Kentucky Counties and UKREC Horticulture! at Princeton

Kelly Jackson, Erika Lyons, Dwight Wolfe, Zenaida Viloria, and Winston Dunwell, Horticulture

Growing bedding plants that perform well with minimal maintenance in Kentucky's climate is important to gardeners. The annual bedding plant trials are a statewide Extension Horticulture effort to determine the best performing species and cultivars of annual flowers for Kentucky. Selected annual flowers were grown at a greenhouse in Elkton, KY. The bedding plants were distributed to the county Extension demonstration gardens in May. Master Gardeners and Extension agents planted the flowers in their trial garden and evaluated them monthly during the season.

Materials and Methods

The goal of the trial garden is to simulate the conditions in a "typical" Kentucky garden. All gardens were mulched with wood chip mulch and received irrigation at planting. Plants received additional irrigation only in the case of drought. Beds were kept as weed free as possible.

Twenty cultivars comprising twelve genera were planted in ten different counties and in western Kentucky (Table 2). From one to twelve people at each county rated their plants on a scale from 0 to 5 (Table 1) each month from June through October. The evaluation was based on the individual gardener's determination of the quality of the plants at a particular site. Data was analyzed using the GLM procedure in SAS v.9.41.

Table 1. Rating scale for evaluating bedding plants.

0 = plants dead
1 = rough--still alive, no color
2 = minimal flowering, faded foliage, significant pest damage
3 = some flowering, may have noticeable pest damage
4 = almost full color/foliage--may have limited pest damage
5 = full color/foliage no pest damage

Results and Discussion

Purple Haze, Bandana® Lemon Zest, and SunPatiens® Spreading Pink Kiss and Compact Tropical Rose averaged statistically significantly higher ratings over the 2017 season than all other cultivars in the trial (Table 2). These taxa showed almost full color of foliage and flowers and limited pest damage at the end of the growing season, with minimum care. Conversely, Surfinia® Summer Double™ Salmon and Headliner™ Pink Sky averaged ratings that were statistically lower than all other cultivars in the trial. They showed poor performance by the mid-growing season.

Table 2. Performance of 20 cultivars throughout the summer of 2017 in western Kentucky.

Genus1	Cultivar	June	July	August	Sept	October	Average
Scaevola	Purple Haze	4.68	4.76	4.64	4.38	3.94	4.55
Lantana	Bandana® Lemon Zest	4.00	4.50	4.73	4.74	4.77	4.51
Impatiens	SunPatiens ® Spreading Pink Kiss	4.14	4.61	4.35	4.54	4.71	4.49
Impatiens	SunPatiens ® Compact Tropical Rose	3.84	4.05	3.80	4.09	4.11	4.03
Portulaca	Colorblast Lemon Twist	3.97	4.26	3.88	3.60	3.40	3.97
Petunia	Ray™ Black Ray™	4.65	4.53	4.16	2.97	2.80	3.88
Tagetes	Strawberry Blonde	4.51	4.45	4.00	3.46	2.26	3.75
Petunia	Amore Queen of Hearts	4.65	4.66	3.90	2.71	2.06	3.64
Salvia	Saucy™ Red	3.39	3.76	3.71	3.69	3.60	3.59
Verbena	Bebop™ Lavender	4.03	4.08	3.27	3.26	3.14	3.58
Petunia	Crazytunia® Moonstruck	4.32	4.14	3.53	2.74	2.57	3.57
Verbena	Lascar™ Dark Violet	4.03	4.03	3.08	3.24	3.11	3.49
Lobularia	Lavender Stream™	3.86	3.92	3.40	3.12	3.00	3.41
Calendula	Cheers™ Orange	3.78	3.53	3.06	2.91	2.43	3.15
Calibrachoa	Minifamous Neo® Orange + Red Eye 17	4.03	3.63	2.61	2.00	1.48	2.85
Bidens	Pop Star	4.03	3.53	2.43	2.09	1.83	2.79
Petunia	Headliner™ Night Sky	4.05	3.63	2.67	1.57	1.26	2.69
Calibrachoa	Colibri™ Cherry Lace	3.68	3.05	2.92	1.97	1.57	2.58
Petunia	Headliner™ Pink Sky	4.03	3.37	2.20	0.89	0.46	2.19
Petunia	Surfinia® Summer Double™ Salmon	3.68	2.21	1.46	0.57	0.31	1.55
Average for each month		4.07	3.93	3.39	2.92	2.64	3.41
Least Significant Difference (0.05)2		0.25	0.22	0.25	0.29	0.28	0.15

1 Arranged in descending order of the average of monthly ratings.
2 Means within column greater than the least significant difference are not statistically significant at the 0.05 probability level.

Performance ratings among cultivars differed significantly at all sites (Table 3), except for Daviess, Mason, and Warren Counties. In those counties, significant differences among cultivars could not be determined since each of these counties had only one individual rate cultivars.

A performance rating that a particular cultivar received in one county typically differed significantly from that received in another county (Table 3). This was true for all cultivars except Colorblast Lemon Twist, SunPatiens ® Compact Tropical Rose, and SunPatiens® Spreading Pink Kiss. The performances of these cultivars did not significantly differ from county to county, which indicates higher adaptability to Kentucky's soils and climate.

Acknowledgments

We wish to thank county Extension agents Jessica Bessin, Mercer County; Macy Fawns, Mason County; Susan Fox, Lyon County; Kristin Goodin, Warren County; Carol Hinton, Breckenridge County; Annette Meyer Heisdorffer, Daviess County; Kelly Jackson, Christian County; Erika Lyons, Hopkins County; Beth Wilson, Pulaski County; UKREC staff Virginia Travis, June Johnston, and Zenaida Viloria, UKREC, Caldwell County; and Master Gardeners at these garden locations for planting, maintaining, and evaluating the annuals in these trials. The demonstration gardens are a good educational activity for Master Gardeners and home gardeners. It is the goal of this program to allow Master Gardeners to see new flowers and compare them to the reliable annual flowers seen in Kentucky gardens and use this information in their volunteer activities.

Table 3. Performance of 20 bedding plant cultivars in seven counties in Western Kentucky.

		Counties in Western Kentucky[2]											
Genus	**Cultivar[1]**	**Breckinridge**	**UKREC**	**Christian**	**Daviess**	**Hopkins**	**Lyon**	**Mason**	**Mercer**	**Pulaski**	**Warren**	**Means**	**LSD[3] (0.05)**
Petunia	Amore Queen of Hearts	2.94	4.53	3.40	3.40	4.65	3.50	4.40	3.47	3.60	3.40	3.64	0.70
Lantana	Bandana® Lemon Zest	4.77	3.80	4.53	5.00	3.75	4.80	4.40	4.67	4.80	4.60	4.51	0.67
Verbena	Bebop™ Lavender	4.31	2.67	4.13	2.80	2.50	3.97	3.60	3.53	3.00	-	3.58	0.71
Calendula	Cheers™ Orange	3.91	3.40	1.53	4.00	0.45	4.07	4.40	3.73	3.00	3.80	3.15	1.04
Calibrachoa	Colibri™ Cherry Lace	3.29	2.60	2.87	2.00	0.45	2.43	3.60	2.40	3.70	4.00	2.58	0.90
Portulaca	Colorblast Lemon Twist	4.09	3.87	4.73	5.00	3.55	4.33	3.80	3.00	3.80	3.00	3.97 ns	1.21
Petunia	Crazytunia® Moonstruck	3.97	3.33	2.90	3.00	2.30	4.20	3.40	3.47	4.30	3.60	3.57	1.07
Petunia	Headliner™ Night Sky	3.57	2.53	2.67	2.20	0.50	3.17	1.60	2.93	2.90	3.40	2.69	0.73
Petunia	Headliner™ Pink Sky	2.46	1.53	2.20	2.00	1.60	2.67	1.80	2.40	2.10	2.00	2.19	0.63
Verbena	Lascar™ Dark Violet	4.20	3.00	3.93	2.80	1.35	4.47	3.80	3.80	2.60	3.40	3.49	0.97
Lobularia	Lavender Stream™	3.97	3.00	2.73	3.00	0.30	4.33	4.00	5.00	3.80	4.20	3.41	0.70
Calibrachoa	Minifamous Neo® Orange+Red Eye 17	3.40	3.27	2.13	0.00	2.25	3.57	1.00	2.07	3.90	3.00	2.85	0.83
Bidens	Pop Star	3.46	2.07	2.53	2.00	2.90	1.77	3.80	3.13	3.90	3.40	2.79	0.74
Scaevola	Purple Haze	4.80	4.73	4.47	0.60	4.40	4.80	4.80	4.67	4.80	-	4.55	0.74
Petunia	Ray™ Black Ray™	4.17	3.80	3.73	1.00	2.90	4.00	4.60	4.73	4.30	4.60	3.88	0.72
Salvia	Saucy™ Red	3.69	3.80	4.40	3.20	0.35	4.57	3.80	3.87	4.70	4.00	3.59	0.77
Tagetes	Strawberry Blonde	4.03	3.73	4.73	4.00	3.10	3.97	4.40	3.13	2.70	3.20	3.75	0.78
Impatiens	SunPatiens® Compact Tropical Rose	3.77	3.87	4.53	4.00	4.50	4.17	4.20	3.07	4.70	3.60	4.03 ns	1.07
Impatiens	SunPatiens® Spreading Pink Kiss	4.57	4.27	4.47	4.00	4.60	4.70	4.80	3.67	4.90	4.40	4.49 ns	0.68
Petunia	Surfinia® Summer Double™ Salmon	3.26	1.47	2.27	0.40	0.20	0.77	1.20	1.47	0.60	1.60	1.55	1.16
Means of each county		3.83	3.26	3.45	2.74	2.33	3.71	3.57	3.41	3.60	3.51	3.41	0.38
LSD (0.05), Least Significant Difference[3]		0.40	0.54	0.43	NA	0.68	0.37	NA	0.60	0.92	NA	0.15	

1 Arranged in alphabetical order within column.
2 Arranged in alphabetical order within rows.
3 Means within columns or across rows that differ by less than the LSD are not statistically significantly different at the 0.05 probability level.
ns, not significantly different at the 0.05 probability level in the analysis of variance.

2017 Research Publications by the UK Nursery/Landscape Faculty

Baker, A., and D.A. Potter. 2017. Building a better monarch butterfly waystation. Greenhouse Product News, June: 36–41.

Baker, A.M., and D.A. Potter 2018. Colonization and usage of eight milkweed (*Asclepias*) species by monarch butterflies and bees in urban garden settings. Journal of Insect Conservation, 1–14. Published online: doi: 10.1007.s10841-18-0069-5.

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