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Evaluation of Container Grown Blueberry Cultivars and the Effects of Gibberellic Acid on Fruit Set and Fruit Quality

VICTOR A. ZAYAS[1] AND PAUL R. FISHER*[1]

[1]*Environmental Horticulture Dept., University of Florida, P.O. Box 110670, Gainesville, FL 32611*

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There is increasing market interest in blueberry as a container ornamental plant with intact flowers or fruit for retail sale to home owners. The objective was to evaluate the performance of several blueberry cultivars as container ornamental plants under natural day conditions in an unheated greenhouse in Gainesville, FL, and the potential for use of gibberellic acid sprays (GA_3) to increase fruit set without decreasing fruit quality. The three southern highbush (*Vaccinium corymbosum*) cultivars tested ('Sunshine Blue', 'Emerald', and 'Biloxi') had high reproductive bud count (109, 59, and 83 buds per plant, respectively). 'Sunshine Blue' had the earliest flowering of these three cultivars (13 Dec. 2013, 17 Jan. 2014, or 5 Jan. 2014, respectively). The upright habit and poor branching of 'Biloxi' were not desirable attributes as an ornamental container plant. Gibberellic acid (GA_3) was applied to 'Emerald' and 'Sunshine Blue' at 100 $mg \cdot L^{-1}$ GA_3 as a foliar spray three times 14 days apart, beginning when each cultivar had the maximum percentage of open flowers. Gibberellic acid (GA_3) hastened date of first green fruit by 17 days and increased fruit number by 47% (to an average 72 fruit/plant), but did not affect the date of first ripe fruit. Fruit weight was increased by 25% using GA_3, but there was no effect on sugar or acid content. Ornamental production of 'Sunshine Blue' and 'Emerald' using gibberellic acid (GA_3) sprays in greenhouses where pollinators may not be present produced attractive fruiting blueberry plants.

Retail value of edible crops such as blueberries grown as container plants is likely to be increased if plants are in flower or fruit. In order to produce plants without blemishes and to extend the marketing season, production in covered structures is a cultural option. Ogden and van Iersel (2009) noted that production of 'Emerald' and 'Jewel' southern highbush blueberries in high tunnel greenhouses in Georgia resulted in 38 to 39 days earlier flowering than outdoor plants. However, low fruit set was noted in high tunnels, probably because of limited pollinator activity during early season flowering.

In an evaluation of southern highbush blueberry cultivars as ornamental container plants, Lopez et al. (2012) found that 'Emerald' and 'Sunshine Blue' had a high flower plus fruit number (bud count) and other positive aesthetic attributes. Because 'Sunshine Blue' has particularly early flowering (in December–January for Gainesville, FL), the absence of pollinators is likely to be an issue.

NeSmith and Krewer (1992) and Williamson et al. (1996) found that two foliar sprays of gibberellic acid (GA_3) at 250 to 300 $mg \cdot L^{-1}$ applied 10 to 18 days apart, increased fruit set in rabbiteye blueberry. Applications of GA_3 is used as a tool to enhance parthenocarpy in highbush and rabbiteye blueberry, however may cause excessively heavy fruit set, plant stress, delayed fruit ripening, and decreased fruit weight in southern highbush blueberry (Williamson et al., 2012).

The objective was to evaluate plant performance of several blueberry cultivars as container ornamental plants under natural day conditions in an unheated greenhouse in Gainesville, FL, and the potential for use of GA_3 sprays to increase fruit set without decreasing fruit quality.

Materials and Methods

Tissue culture 72-count liners of two northern highbush blueberries including 'Peach Sorbet' (*V. corymbosum* hybrid 'ZF06-043') and 'Jelly Bean' (*V. corymbosum* 'Jelly Bean'), three southern highbush including 'Emerald' (*V. corymbosum* hybrid 'Emerald'), 'Sunshine Blue' (*V. corymbosum* 'Sunshine Blue') and 'Biloxi' (*V. corymbosum* hybrid 'Biloxi'), along with one lowbush variety 'Top Hat' (*V. corymbosum* x *V. angustifolium*) were planted in 15-cm (6 inch)-diameter pots filled with a peat : perlite (70% : 30% by volume) unlimed substrate at the University of Florida in Gainesville, FL, on 10 Feb. 2013, where they were housed for the remainder of the experiment. Plants were pruned 8–10 cm (3–4 inches) above the substrate every four weeks until 4 Oct. 2013.

Plants were fertigated beginning on 5 May 2013 with 100 $mg \cdot L^{-1}$ N of water soluble fertilizer including micronutrients (15.0-2.2-12.5, 20.0-4.4-16.6, and 11.0-0.9-5.0 at different crop stages), along with a controlled release fertilizer 18.0-13.2-10.0 (Osmocote 18-6-12, Everris, Dublin, OH) top-dressed at a medium label dose of 11 grams/plant on 15 May 2013.

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*Corresponding author. Email: pfisher@ufl.edu

Table 1. Average monthly air temperatures at the Gainesville location.

13 May	13 June	13 July	13 Aug.	13 Sept.	13 Oct.	13 Nov.	13 Dec.	14 Jan.	14 Feb.	14 Mar.	14 Apr.	14 May	14 June
27.4 °C	27.8 °C	27.6 °C	28.6 °C	26.8 °C	23 °C	18.2 °C	17.2 °C	11.5 °C	16.5 °C	18.3 °C	23.4 °C	26.4 °C	28.2 °C

Table 2. Comparison of first open flower, first green fruit, and first ripe fruit dates, as well as the maximum number of combined flowers and fruit per plant during any of the weekly measurement dates from Nov. 2013 through June 2014 for blueberry cultivars with no GA_3 applications. Blueberry cultivar 'Jelly Bean' yielded no ripe fruit.

Variable	Significance	Biloxi	Emerald	Jelly Bean	Peach Sorbet	Sunshine Blue	Top Hat
First open flower	***	5 Jan. b	17 Jan. b	2 Apr.a	2 Feb. a	13 Dec. bc	25 Nov. c
First green fruit	***	10 Feb. c	25 Feb. bc	9 May a	19 Mar. b	29 Jan. cd	6 Jan. d
First ripe fruit	ns	24 Apr. a	27 Apr. a	No Ripe Fruit	3 May a	16 Apr. a	23 Mar. a
Maximum # of flowers & fruit	***	83.3 ab	58.7 bc	4.5 d	42.5 c	109.1 a	46.9 bc

*** = significant at $P \leq 0.001$ level.
ns = not significant at $P \leq 0.05$ level.

Ten plants per cultivar for experiment one (total six cultivars x 10 potted plants = 60 potted plants) along with 38 'Emerald' plants (26 without GA_3 and 12 with GA_3) and 32 'Sunshine Blue' plants (22 without GA_3 and 10 with GA_3) plants divided in a 2 : 1 ratio were grown at the Gainesville location in an unheated greenhouse covered in a single polyethylene sheet. Plants in experiment 2 were divided in a two to one ratio to ensure adequate number of fruit from control treatments for physical and quality analyses. Plants in experiment 2 were treated with GA_3 (ProGibb plus 2X, Valent Biosciences Corp., Libertyville, IL) at 100 $mg \cdot L^{-1}$ active ingredient. The plants that received the GA_3 treatment received a total of three applications, 14 days apart, beginning on the date when each plant reached a peak percentage of open flowers.

The greenhouse contained a temperature data logger in an enclosure that collected hourly air temperature (Table 1). Dates of first open flower, green and mature fruit were recorded for each plant and the number of flowers, green and mature fruit were recorded once a week for both experiments, along with the date of each GA_3 application for experiment 2. Each week the plants were categorized into stages which provided a description of the plant at the time of recording.

In experiment 2, fruit was harvested when the respective plants reached 50% to 70% total fruit maturity. Three berries were selected from the total harvest from each plant, and berry weight, fruit diameter, firmness (FirmTech 2; BioWorks, Inc., Wamego, KS), and color by reflectance spectrometry (CM-2002 photospectrometer; Konica Minolta, Inc., Ramsey, NJ) were recorded and averaged per plant.

Once the initial set of data was taken, the remaining harvested fruit were homogenized using a mortar and pestle. This homogenized sample was centrifuged and the supernatant liquid was collected. Soluble solids content (%-Brix using a PAL-1 "Pocket" Refractometer; Atago U.S.A. Inc., Bellevue, WA) and total titratable acidity (%-citric acid) were measured.

Data for the experiment were analyzed using ANOVA in PROC GLIMMIX in SAS V9.2 to calculate the main and interaction effects for cultivar and gibberellic acid factors on all measured variables (timing and duration of flowering, green and mature fruit phases, the maximum number of flowers or fruit, and fruit quality parameters).

Results and Discussion

Flower and fruit development across six cultivars. Cultivars differed in date of first open flower, first green fruit, and maximum flower and fruit number with both main and interaction effects ($P < 0.01$), but showed no difference in date of first ripe fruit. Under natural north Florida climate conditions, 'Top Hat' had the earliest first open flower, first green and ripe fruit, followed by 'Sunshine Blue', 'Biloxi', 'Emerald' and ''Peach Sorbet' (Table 2). 'Jelly Bean' did not form ripe fruit. By averaging the dates across cultivars in Table 2, green fruit formed an average of 41 days after first open flower and ripe fruit matured an average of 72 days after green fruit formation. 'Peach Sorbet' had a rapid reproductive cycle from flower to fruit, producing green fruit only 17 days after first open flower, and ripe fruit 45 days after first green fruit.

Cultivars differed in the number of combined flowers and fruit produced. 'Sunshine Blue' and 'Biloxi' had the highest flower and fruit count, followed by 'Emerald', 'Top Hat', and 'Peach Sorbet' (Table 2). 'Jelly Bean' performed poorly in comparison to all other cultivars with a maximum flower and fruit number of 4.5.

Gibberellic acid spray effects on 'Emerald' and 'Sunshine Blue'. Gibberellic acid (GA_3) sprays were applied during peak flowering and therefore did not affect date of first flower (Table 3). Plants that received GA_3 applications developed green fruit on average 17 days earlier than plants that did not receive GA_3. Applications of GA_3 did not affect date of first ripe fruit, however, because the period of fruit ripening after the green fruit stage (fruit development period, or FDP) was longer for GA_3 treated plants (76 days compared with 64 for control plants). These results are consistent with experiments performed on the effects of GA_3 on fruit set and yield of rabbit eye blueberries (Williamson et al., 1996), where the FDP of GA_3 treated plants was 10 days longer than plants not treated. For sale of blueberries as ornamental plants, an extended FDP may not be as important as for field fruit production, because presence of green fruit is an aesthetic benefit for a containerized plant.

Plants treated with GA_3 had 25% more flowers and fruit compared with the control group (maximum number of flowers and fruit of 101 and 75, respectively, Table 3). The GA_3 applications produced attractive containerized plants (Fig.1), although some additional shoot elongation occurred which could potentially

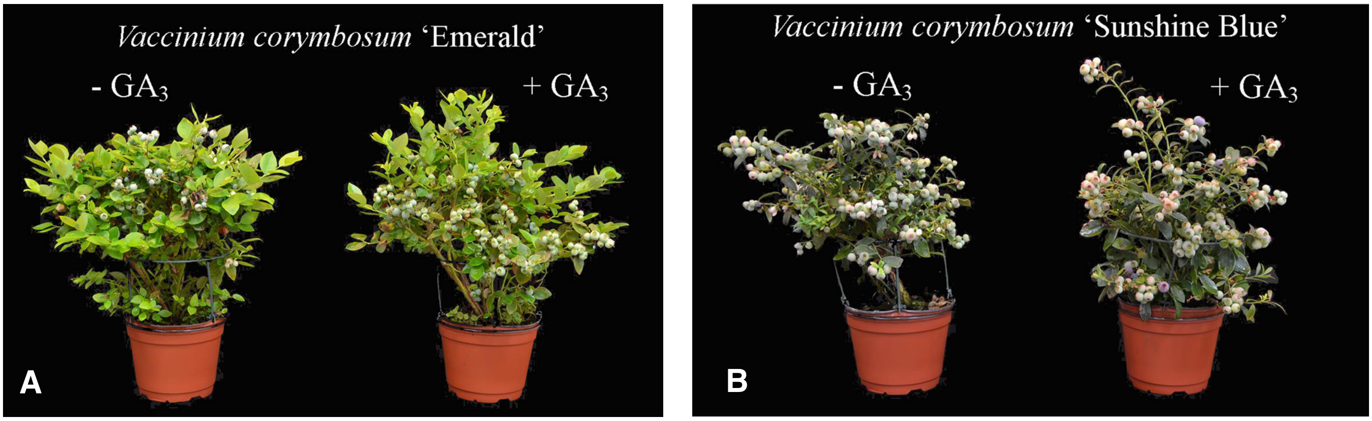

Fig. 1. (**A**) 'Emerald' and (**B**) 'Sunshine Blue' blueberry plants with photographs taken on March, 2014, with and without three foliar spray applications of 100 mg·L^{-1} gibberellic acid.

Table 3. Effect of gibberellic acid (GA_3) sprays on fruit development and quality for 'Emerald' and 'Sunshine Blue' cultivars.

Variable	Cultivar	GA_3	Cultivar*GA_3	Emerald	Sunshine Blue	No-GA_3	GA_3
First open flower	***	ns	ns	Jan.17 a	Dec.13 b	Jan.3 a	Dec.26 a
First green fruit	***	*	ns	Feb.25 a	Jan.29 b	Feb.17 a	Jan.31 b
First ripe fruit	**	ns	ns	Apr.27 a	Apr.16 b	Apr.22 a	Apr.17 a
Maximum # of flowers & Fruit	***	*	ns	59 b	109 a	75 b	101 a
Maximum fruit #	***	**	ns	31 b	84 a	49 b	72 a
Maximum flower #	*	ns	ns	46 b	83 a	60 a	74 a
Average firmness (g/mm of deflection)	ns	ns	ns	232 a	231 a	220 a	250 a
Average diameter (mm)	*	ns	ns	13.5 a	12.6 b	12.8 a	13.2 a
Weight per berry (g)	**	**	ns	1.01 a	0.80 b	0.81 b	1.01 a
Soluble solids content (%-Brix)	ns	ns	**	7.89 a	8.10 a	8.09 a	7.90 a
Titratable acidity (%-citric acid)	***	ns	ns	51% b	102% a	84% a	76% a
Color (Lx)	***	ns	ns	33.79 a	27.44 b	29.87 a	30.27 a
Color (ax)	**	*	*	3.60 a	2.83 b	2.86 b	3.60 a
Color (bx)	***	ns	ns	–6.84 b	–3.06 a	–4.39 a	–4.95 a

*, **, *** = significant at $P \leq 0.05$, 0.01, or 0.001 level, respectively.
ns = not significant at $P \leq 0.05$ level.

cause excessive height or weak stems if GA_3 was over-applied. The increased combined flower and fruit number occurred because GA_3 treated plants had an average of 23 more fruit per plant than control plants (72 and 49 fruit per plant respectively), even though there was no difference in flower number.

Berry fresh weight was affected by cultivar and gibberellin application. 'Emerald' had heavier berries than 'Sunshine Blue' (1.01 g and 0.80 g, respectively). Berry fresh weight also increased 25% in plants sprayed with GA_3, 1.01 and 0.81 grams for GA_3 treated and untreated, respectively. 'Emerald' had larger berries than 'Sunshine Blue' (13.5 mm vs. 12.6 mm in diameter), but GA_3 did not affect berry diameter. Firmness was unaffected by cultivar or GA_3 applications.

No difference was found in the soluble solid content (%-Brix) between cultivars or between the GA_3 treatment and control groups. However, a significant interaction between cultivar and GA_3 applications for %-Brix was observed. The %-Brix decreased in 'Emerald' plants when GA_3 was applied, whereas 'Sunshine Blue' plants had higher sugar content with GA_3. Total titratable acidity was higher in 'Sunshine Blue' plants than 'Emerald' plants, but GA_3 had no effect.

Fruit color using reflectance spectrometry and the CIELAB system differed between cultivars for all color parameters. A significant interaction occurred between cultivar and GA_3 for the x-variable, whereby 'Emerald' plants treated with GA_3 had slightly redder fruit than the controls, whereas 'Sunshine Blue' experienced no change in color with GA_3.

Conclusions

Ornamental production of container blueberries requires cultivars that exhibit a compact and well-branched growth habit, and provide aesthetic value in regards to foliage, flowering and fruiting. Cultivars suitable for ornamental production in Florida should also have low chilling requirements and evergreen growth under greenhouse conditions. Overall, 'Emerald' and 'Sunshine Blue' showed the most desirable fruiting and branching characteristics, consistent with previous trials (Lopez et al., 2012). 'Peach

Sorbet' produced flowering later than 'Emerald' and 'Sunshine Blue', but was compact and had attractive foliage. 'Biloxi' had poor branching and yielded plants that were not very compact or aesthetically pleasing. 'Jelly Bean' apparently did not receive adequate chilling for the Gainesville, FL, location and performed poorly. 'Top Hat' flowered very early and was compact, however most fruit did not fully develop; this cultivar is more suited to northern U.S. locations.

We observed that three applications of gibberellic acid at 100 $mg \cdot L^{-1}$ active ingredient, 14 days apart, beginning on the date when each plant reached a peak percentage of open flowers, hastened fruit formation by 17 days, but resulted in an increase of 12 days in the overall fruit development period. Gibberellic acid application also resulted in an increase in fruit set of 47% when compared to plants not treated. Fruit quality analysis found that applications of GA_3 did not affect diameter, firmness, soluble solid content (%-Brix), total titratable acidity (%-citric acid) and color (Lightness [Lx-variable] and blue to yellow axis [bx-variable]). Applications of GA_3 increased fruit weight by 25% compared with untreated plants. Gibberellic acid applications could be beneficial in greenhouse settings where natural pollinator populations are not present.

Literature Cited

Lopez, J.E., P.R. Fisher, and S. Steed. 2012. Scheduling of flowering and fruiting of southern highbush blueberry as a container ornamental plant. Proc. Fla. State Hort. Soc. 2012. 125:312–316.

NeSmith, D.S. and G. Krewer. 1992. Flower bud stage and chill hours influence the activity of GA_3 applied to rabbiteye blueberry. HortScience 27:316–318.

Ogden, A.B. and M.W. van Iersel. 2009. Southern highbush blueberry production in high tunnels: Temperatures, development, yield, and fruit quality during the establishment years. HortScience 44:1850–1856.

Spann, T.M., J.G. Williamson, and R.L. Darnell. 2003. Photoperiodic effects on vegetative and reproductive growth of *Vaccinium darrowi* and *V. Corymbosum* interspecific hybrids. HortScience 38:192–195.

Williamson, J.G., J.W. Olmstead, and P.M. Lyrene. 2012 Reproductive growth and development of blueberry. UF/IFAS Extension Bulletin HS976.

Williamson, J.G., R.L. Darnell, G. Krewer, and S. NeSmith. 1996. Gibberellic acid (GA_3) sprays increase fruit set and yield of rabbiteye blueberries. Proc. Fla. State Hort. Soc. 109:212–214.