

GIBBERELIC ACID (GA₃) SPRAYS INCREASE FRUIT SET AND YIELD OF RABBITEYE BLUEBERRIES

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Abstract. Field and growth chamber experiments were conducted in north Florida to determine the effect of GA₃ sprays on fruit set and yield of rabbiteye blueberries (*Vaccinium ashei* Reade). In the 1992 field experiment, split applications of GA₃ (250 ppm) sprayed at 80-90% full bloom and again 10 days later increased fruit set and yield of 'Beckyblue' and 'Bonita' rabbiteye blueberries. In 1993, two or three GA₃ sprays (250 ppm) increased fruit yield of field-grown 'Tifblue' rabbiteye blueberries. Average fruit weight was decreased and fruit development period (FDP) was increased by GA₃ treatment both years. Similarly, GA₃ application to non-pollinated flowers under controlled environmental conditions increased percent fruit set, decreased average fruit weight, and increased FDP when compared to hand-pollinated fruit. High night temperature (21C) during and immediately after bloom reduced fruit set and average fruit weight compared to 10C night temperature for both hand-pollinated and GA₃-treated fruit. Yield enhancement of rabbiteye blueberry from bloom sprays of GA₃ is probably greater during years with low natural fruit set compared to years with high natural fruit set.

Poor fruit set limits yields of rabbiteye blueberry in the southeastern United States. (Williamson and Lyrene, 1995; Mainland, 1985). Fruit set is especially low on large rabbiteye plantings and in years when bloom periods of inter-planted cultivars do not overlap. Although the causes of poor fruit set in rabbiteye blueberry are not clear, poor pollination, high temperatures during flowering, and insects and diseases have been suggested as possible explanations for post-bloom fruitlet drop (Lyrene and Crocker, 1985). Gibberellic acid (GA₃) has been used to increase fruit set and yield of highbush blueberry (*V. corymbosum*) for many years, but it was slow to be adopted as a commercial practice for rabbiteye blueberries because of discouraging research results (Austin, 1979; Davies, 1986; Davies and Buchanan, 1979; Mainland, et. al., 1979).

In 1990, field tests in south Georgia showed large increases in yield of 'Climax' and 'Tifblue' rabbiteye blueberries when bloom sprays of GA₃ were used. Comparison of these re-

sults with earlier reports suggested that timing of GA₃ sprays was critical for effectiveness at increasing fruit set and yield of rabbiteye blueberry. Generally, GA₃ applications at, or near, full bloom appeared to be most effective. The first objective of this study was to determine if multiple GA₃ sprays, applied during and shortly after full bloom, would increase fruit set and yield of rabbiteye blueberry.

Prior to initiation of our experiments, several grower trials had been conducted in south Georgia and north Florida to evaluate the effects of bloom and post-bloom GA₃ sprays on fruit set of rabbiteye blueberry. Results of these trials suggested that GA₃ sprays might be more effective in south Georgia than in north Florida. Since air temperatures differ between the two regions, and air temperatures during bloom can affect fruit set of other crops (Ahmadi and Stevens, 1979; Charles and Harris, 1972), a second objective of this research was to determine if air temperature affects fruit set of rabbiteye blueberry flowers receiving GA₃ sprays or hand pollination during bloom.

Materials and Methods

1992 Field Experiment. The experiment was located in Waldo, Florida, (Alachua County) in a commercial planting of 6-year-old 'Beckyblue' and 'Bonita' rabbiteye blueberries. Both cultivars were sprayed with split applications of 250 ppm GA₃ (Pro-Gibb, 4%, Abbott Laboratory, N. Chicago, IL) plus 0.1% nonionic surfactant buffered to pH 3.1. Sprays were applied to run-off with a hand-held sprayer. The first application was at 80-90% full bloom (March 9) and the second spray was applied 10 days later. Control plants were sprayed with water containing 0.1% nonionic surfactant and buffered to pH 3.1. All sprays were applied during the early evening to increase drying time. Five shoots per plant were tagged and the flower number on each shoot was determined prior to GA₃ application. Percent fruit set was determined by counting the number of fruit on each tagged shoot on May 19.

1993 field experiment. The experiment was conducted in Earleton, Florida, (Alachua County) in a 20+ year-old planting of 'Tifblue' rabbiteye blueberry plants. The plants were sprayed to drip using a hand-held sprayer with 250 ppm GA₃ (Pro-Gibb, 4%) with 0.1% surfactant and buffered to pH 3.1. There were three treatments: 1) GA₃ applied five days after full bloom (April 7) and again 12 days after full bloom (April 14); 2) GA₃ applied five days after full bloom, 12 days after full bloom, and 60 days after full bloom; 3) controls were sprayed with water containing 0.1% surfactant at all three spray dates. Fruit were hand-harvested on five dates from one randomly selected plant per 5-plant plot. Fruit yield and average fruit weight were determined at each harvest date. A randomized complete block design was used.

Growth chamber experiment. Two-year-old 'Beckyblue' plants were grown outdoors in 1-gal. pots containing peat:pinebark (1:1 v/v) potting medium. Flowers were thinned to about 60/plant in late March, 1993. The remaining flowers were emasculated and sprayed with 250 ppm GA₃ (Pro-Gibb, 4%) with 0.1% surfactant and buffered to pH 3.1, or hand-pollinated with 'Climax' pollen. After treatment, plants were immediate-

ly placed in one of three growth chambers which provided the following day/night temperature regimes: 1) 26C day/21C night; 2) 26C day/10C night; or 3) 29C day/10 C night. Photosynthetic photon flux averaged 500 to 600 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and photoperiod was 8 h. After four weeks, plants were moved to a greenhouse (mean day/night temperatures = 26C/23C) for the remainder of the experiment. A randomized complete block design with single-plant plots was used.

Results

1992 field experiment. GA_3 sprays increased fruit set of both rabbiteye cultivars compared to controls. For 'Beckyblue', average fruit set was 4% for controls and 36% for the GA_3 treatment. For 'Bonita', fruit set was 18% for controls and 65% for the GA_3 treatment. Yield of both cultivars was also increased with GA_3 treatments but the increase was not proportional to that observed for fruit set. For both cultivars, yield was approximately doubled for the GA_3 treatment compared to controls (Table 1) as compared to a 3 to 9-fold increase for fruit set. Many GA_3 -treated fruit remained small and green throughout the harvest period. These immature fruit were never harvested and may account for the differences between fruit set increases and yield increases from the GA_3 sprays.

Fruit yield for 'Beckyblue' was highest at harvest date 1 and did not differ between treatments (yield by harvest date not reported), suggesting that most of the fruit harvested at this date was pollinated. Yield was greater for the GA_3 -treated plants than for controls at harvest dates 2 through 5. For 'Bonita', fruit yield was highest at harvest date 4. There was no difference in yield between treatments at harvest 1, but yields were higher for the GA_3 treatment than for the controls at harvest dates 2 through 4.

Average fruit fresh weight of 'Bonita' was slightly less for GA_3 -treated fruit than for controls (Table 1). Average fruit fresh weight of 'Beckyblue' was not affected by GA_3 sprays.

1993 field experiments. GA_3 sprays increased fruit yield of 'Tifblue' rabbiteye blueberry compared to the control (Table 2). The relative increase of about 2.5x was similar to the increase observed from GA_3 in 1992 with 'Beckyblue' and 'Bonita'. As in 1992, increased yield for GA_3 sprays was noted at all but the first harvest date (yield by harvest date not reported). The greatest increase in yield occurred at the last two harvest dates when approximately 3 to 6 times as much fruit was harvested from the GA_3 -treated plants as from control plants. Total fruit yield and yield at most harvest dates did not differ for two applications of GA_3 vs. three applications of GA_3 (Table 2).

Average berry fresh weight was less for the GA_3 -treated fruit compared to the control fruit (Table 2). The additional GA_3 spray, applied at 60 days after bloom, did not increase average fruit weight over that of the usual bloom plus post-bloom, split-application, spray of GA_3 .

Growth chamber experiment. There were no temperature by pollination treatment interactions. GA_3 treatment increased percent fruit set over hand pollination (Table 3). Average fruit weight was less for GA_3 -treated plants than for hand-pollinated plants, even with low fruit loads of fewer than 60 berries per plant. Average fruit development period was increased by 10 days for the GA_3 treatment compared to hand pollination.

Day/night temperatures during and immediately after bloom affected fruit set and fruit fresh weight. The 26C/10C treatment increased fruit set compared to the 26C/21C treatment and increased average fruit weight compared to either of the other two temperature regimes. Thus, fruit set was reduced by high night temperature (21C) and average fruit fresh weight was reduced by high night (21C) and high day (29C) temperatures.

Discussion

Contradictory results from previous studies on the effects of GA_3 sprays to increase fruit set and yield of rabbiteye blueberry may be due, in part, to differences in rate, timing, and frequency of application. In 1992, NeSmith and Krewer identified stage 5 of flower bud phenology (just prior to corolla opening) (Spiers, 1978) as optimum for GA_3 sprays to increase fruit set. In our studies, fruit set and yield of rabbiteye blueberry were increased by multiple GA_3 sprays, timed to begin when the majority of flowers were close to, or at, stage 5 of flower bud phenology. However, GA_3 sprays did not completely alleviate light cropping of some rabbiteye cultivars. Although yields of GA_3 -treated plants were increased by about 100% over controls, they were still relatively low for 'Beckyblue' and 'Bonita'. However, yields of 'Tifblue' were high (averaging about 19 lbs./plant) which may have been close to the maximum bearing capacity of the bushes. In Georgia grower trials, fruit yields were increased more by GA_3 sprays during years with low natural fruit set. Although the usefulness of GA_3 sprays to increase fruit set and yield of rabbiteye blueberry varied with year, cultivar, and location, our results are more promising than those reported previously (Austin, 1979; Davies, 1986; Davies and Buchanan, 1979).

Average fresh fruit weight was less for GA_3 -treated fruit than for control fruit in field and growth chamber studies. A significant decrease in fruit weight was observed in the growth chamber study, even with low fruit loads of less than 60 fruit per plant. A similar reduction in fruit weight was noted for field-grown 'Tifblue' plants where flowers and fruit were not thinned and yields were high. Therefore, reduced fruit size (weight) commonly observed with GA_3 -treated blueberries is not a response to heavier crop loads, but a direct effect of GA_3 treatment. There was no apparent benefit in fruit size from the delayed GA_3 application at 60 days after full bloom.

Table 1. Effect of GA_3 on seasonal fruit yield, average fruit weight and fruit development period of 'Beckyblue' and 'Bonita' rabbiteye blueberries.

Treatment	Yield (lbs/bush)		Average fruit wt. (g/fruit)		FDP (days) ^a	
	'Beckyblue'	'Bonita'	'Beckyblue'	'Bonita'	'Beckyblue'	'Bonita'
Control	1.5	1.8	1.4	1.7	82	97
GA_3	3.3	3.1	1.4	1.6	96	103
Significance	*	**	ns	*	*	*

^aFruit development period. (days from 50% bloom to first harvest)

ns, *, ** nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 2. Effect of GA₃ on seasonal fruit yield and average fruit weight of 'Tifblue' rabbiteye blueberry.

Treatment	Yield (lbs/bush)	Average fruit weight (g/berry)	FDP ^a
Control	8.2 b	1.3 a	93 b
GA ₃ ^b (2 app.)	21.4 a	0.9 b	98 a
GA ₃ ^c (3 app.)	18.3 a	0.9 b	98 a

^aFruit development period. (days from 50% bloom to first harvest)

^bMean separation by Duncan's Multiple Range test, 0.05%.

^cGA₃ (250 ppm) sprayed to drip 5 and 12 days after full bloom.

^dGA₃ (250 ppm) sprayed to drip 5, 12 and 60 days after full bloom.

FDP was increased for GA₃-treated fruit in all three experiments. Average FDP of GA₃-treated 'Beckyblue' fruit was increased by 10 days over hand-pollinated fruit in the growth chamber study. In the field experiments, FDP's were from 5 ('Tifblue') to 14 ('Beckyblue') days longer than for control fruit. This agrees with work by Krewer, et. al. (1991), and with observations made throughout south Georgia and north Florida where GA₃ has been used in commercial plantings.

Night air temperatures during pollination, and shortly thereafter, may influence fruit set and growth of blueberry. Fruit set and average fruit weight were greater for the 26C day/10C night temperature regime than for the 26C day/21C night temperatures, regardless of whether flowers were hand pollinated or sprayed with GA₃.

Conclusions

Two applications of GA₃ beginning at stage 5 of flower bud phenology increased fruit set, yield, and FDP of several rabbiteye blueberry cultivars. The increases in yield of GA₃-treated plants relative to non-treated controls were similar for the north Florida experiments and the south Georgia grower trials, but they varied considerably with location and year. The amount of natural fruit set probably influenced the effectiveness of GA₃ sprays at increasing yields over the controls. GA₃-treated fruit were smaller and delayed in maturity compared to non-treated fruit. The increased FDP of GA₃-treated fruit may be more critical for north Florida than for south Georgia because of Florida's emphasis on early, fresh-market blueberries.

Current recommendations call for initial GA₃ application when the largest percentage of flowers are at stage 5 of flower bud phenology. Good results can be obtained with two applications of 24-32 ounces of Pro-Gibb (a 4% GA₃ liquid concentrate) per acre (48-64 ounces of Pro-Gibb per acre total) in 40 gallons of water per acre, spraying both sides of the bushes each time. Where two cultivars with different bloom dates are inter-planted, the first and second sprays can be directed toward the first cultivar to bloom. The third and fourth sprays

Table 3. Temperature and pollination effects on fruit set and development of 'Beckyblue' rabbiteye blueberry.

Main effect	Fruit set (%) ^a	Average fruit wt. (g)	FDP ^b (days)
Day/night temperature (°C)			
26/21	63.9 b ^c	1.5 b	85 b
26/10	83.2 a	1.7 a	88 ab
29/10	71.4 ab	1.4 b	90 a
GA ₃ /Pollination			
GA ₃	79.8 a	1.2 b	93 a
Pollination	66.1 b	1.9 a	83 b

^aData were arc sin transformed prior to analysis.

^bFDP=fruit development period.

^cMean separation by Duncan's Multiple Range test, 5% level (temperature) and t-test, 5% level (pollination).

can be directed toward the later-blooming cultivar.^dThe total amount of Pro-Gibb (4% GA₃ liquid concentrate) applied per season should be between 48-64 ounces per acre. It is best to apply GA₃ during periods of slow drying such as at night, in the evening, or very early in the morning. GA₃ should not be applied to rabbiteye blueberry bushes that are in a low state of vigor. Southern highbush cultivars often set more fruit than they can properly mature. Spraying these cultivars with GA₃ can increase this problem.

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