Title: Affecting Fruit Set with Gibberellic Acid and Coconut Oil Soap Emulsifier in Rabbiteye Blueberry 'Premier' and 'Brightwell' under Field Conditions

Progress Report

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Research Proposal

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Objective: To identify the response of rabbiteye blueberry (*Vaccinium virgatum* Aiton syn, *ashei*) to GA_3 and coconut oil soap emulsifier on fruit set, yield, and fruit quality under field conditions.

Justification and Description:

For blueberry growers in the southeastern U.S., rabbiteye blueberry cultivar 'Premier' has been considered a desirable cultivar for production. 'Premier' was released in 1978 through collaborative breeding efforts by North Carolina State University and the USDA. 'Premier' harvest is early to mid-season, which mixes into late southern highbush blueberry (*V. corymbosum* L. interspecific hybrid) harvest in South Georgia. The fruit are large, of excellent quality, and the plant is vigorous (Eck, 1988). However, 'Premier', along with other rabbiteye blueberry cultivars with 'Ethel' in their pedigree, displays floral polymorphism or misshapen flowers that discourage pollination by honey bees (*Apis mellifera* L.) (Sampson et al., 2013). Even blueberries without floral polymorphism, honey bees have difficulty entering the long narrow flowers, with a tight aperture, to access the nectaries (Eck, 1988). Fruit set in blueberry is further diminished by nectary robbery from carpenter bees (*Xylocopa virginica* L.) (Sampson et al., 2004). Nectary robbery can be observed as a lateral perforation of the corolla from which both honey bees and carpenter bees will draw nectar (Dedej and Delaplane, 2004). Further,

Dedej and Delaplane (2004) observed in rabbiteye blueberry 'Climax' that fruit set was reduced when honey bees were absent but carpenter bees present, which suggests that multiple honey bee visits are pollinating blueberry flowers regardless of nectary robbery.

Blueberry pollination is also affected by weather. When conditions are overcast, cold, raining, and/or foggy/misty, honey bee flower visits are significantly reduced; however, bumble bees were still active (Tuell and Isaacs, 2010). Tuell and Isaacs (2010) also reported that fruit set, berry weight, mature seeds, or estimated yield were not affected by weather conditions. Their study was conducted with highbush blueberry (*V. corymbosum* L.), which are self-fertile and parthenocarpic (Eck, 1988). Rabbiteye blueberry is less self-fruitful and cross-pollination is crucial for fruit set (Retamales and Hancock, 2012). Growers are aware of these conditions and gibberellic acid is used to improve fruit set in rabbiteye blueberry.

From work conducted by NeSmith and Krewer (1992, 1997) and NeSmith et al. (1995), a recommendation for 4% gibberellic acid isomer 3 (GA_3) at 24-32 oz/A in 40 gal water/A, two applications, starting at 40-50% bloom and 10-18 days later was developed (Krewer et al., 2016). In 2016, I conducted an experiment with Progibb® 4% (Valent BioSciences Corp., Libertyville, IL, USA) on 'Premier' blueberry with two applications at 30 oz/A, one application at 30 oz/A, and one application at 80 oz/A. The first application (two application treatment) was at 40-50% bloom and the second (single application treatments) was 7 days later. All rates and timings were in accordance with Valent recommendations. None of the treatment's yield were significantly different than the untreated plants; nor, where there any significant differences in fruit quality measurements of weight or sugar acid ratio. My yield findings were consistent with observations that growers in the region were reporting in 2016 from GA_3 applications to 'Premier'. In a greenhouse study using 250 ppm GA_3, NeSmith and Krewer (1997) observed a 25% increase in fruit set with a single application at 5-6 stage of flower development in eight rabbiteye cultivars; however, unlike 'Brightwell', 'Tiftblue' and 'Briteblue', 'Premier' fruit set was not increased with a second application of GA_3. Interestingly, Dedej and Delaplane (2004) observed in plots where pollinators were excluded the average fruit set was 25.1%, which was similar to the fruit set I observed throughout all treatments in my 2016 study with 'Premier'. Further, Sampson et al. (2014) reported that the use of 10% coconut oil soap (a mix of deionized water and soap to 0.5% V/V) (Ready-For-Use hand soap, Carroll Co., Garland, TX) as an emulsifier with 250 ppm GA_3 significantly improved fruit set in 'Premier' when comparing GA_3 + unpollinated flowers with soap emulsifier to manually pollinated flowers. However, field results showed that GA_3 + pollination were not significantly different than flowers without the GA_3 application, which suggests that coconut oil soap used in the study increased fruit set.

In my GA_3 study, I did not use a surfactant nor did Valent request its use. In the Sampson et al. (2014) study, a second experiment compared the surfactant Silwet L-77 (Helena Chemical Co. Collierville, TN, USA) to the soap and water. Fruit yield under Silwet applications were significantly lower than the water, water/soap, and water/soap/GA_3, which suggested the Silwet inhibits yield. For this proposal, a comparison of GA_3, coconut oil soap, Silwet applications in a grower cooperative field trial was to be analyzed to determine the effect on production in 'Premier' and 'Brightwell'. 'Brightwell' is being included because of the strong response to GA_3. In the NeSmith and Krewer (1997) study, 'Brightwell' was observed to have a 74% increase in fruit set with 250 ppm applications of GA_3.The main goal of the proposed study was

to evaluate ‘Premier’ and ‘Brightwell’ response to GA_3 applications with and without coconut oil soap as an emulsifier.

Experimental Plan:

Materials
‘Premier’ and ‘Brightwell’ eight years from planting at a farm in Pierce County, GA, coconut oil soap, GA3, Silwet, backpack sprayer, collection bags, harvest lugs, buffering agent,

Treatments
In a complete block design, three blocks were to be evaluated with 3-5 plants within each treatment. There are two cultivars being analyzed; ‘Premier’ because of polymorphism and difficulty to set fruit; ‘Brightwell’ because the cultivar has shown positive response to GA_3 treatments. Treatments were to be:

1) Untreated
2) GA_3 38 oz/A using 40 gal/A or 250 ppm solution
   Single application at 40% – 50% bloom
3) GA_3 250 ppm
   Two applications 40% - 50% bloom and 10-14 days later
4) GA_3 250 ppm and 0.5% (v/v) coconut oil soap
   Two applications 40% - 50% bloom and 10-14 days later
5) GA_3 250 ppm with 0.25% (v/v) Silwet-77
   Two applications 40% - 50% bloom and 10-14 days later
6) 0.5% (v/v) coconut oil soap
   Two applications 40% - 50% bloom and 10-14 days later
7) 0.25% (v/v) Silwet-77
   Two applications 40% - 50% bloom and 10-14 days later

Application was via backpack sprayer to dripping.

Analyses
Treatments will be evaluated for:

1) Flower bud and flower count
   On each bush within each treatment, a random limb will be tagged, at full bloom a count of the flower buds and flowers will be taken.
2) Crop set estimate will be made from the same tagged branches, where set fruit will be counted 4-6 weeks after full bloom
3) Harvest will be conducted on a weekly basis starting at ~20% ripe
   Yield will be measured as weight per bush
   A subsample will be evaluated for fruit quality (100 fruit weight, soluble solids concentration, % acidity, color, and seed count
4) Phytotoxic effects will be monitored

Revised Experiment
Freezing weather from 14 Mar. to 16 Mar. caused damage to flowers and set fruit to the extent where some blueberry growers without freeze protection had a total loss. ‘Premier’ in our study

was also severely damaged by the freezing weather. Instead of terminating the experiment, we modified our GA_3 applications to identify if GA_3 could mitigate freeze damage and improve yield. We reduced the treatments to:

1) Untreated
2) GA_3 38 oz/A using 40 gal/A or 250 ppm solution
   Two applications with the second application 10-14 days later
3) GA_3 250 ppm and 0.5% (v/v) coconut oil soap
   Two applications with the second application 10-14 days later

At the Pierce County site, we applied the treatments on 24 Mar. and 4 Apr. to 'Brightwell' and 'Premier' with a backpack sprayer to dripping. The applications were as a complete block design with two blocks and five contiguous plants per treatment. Two harvests were conducted and yield as total weight per bush was collected. From each treatment during each harvest, a sample of fruit was evaluated for fruit quality as 100 fruit count weight (g), soluble solids (Brix), % acid (0.1 N NaOH titrated to endpoint of pH 8.2), and solution pH.

At the University of Georgia Blueberry Farm in Alapaha, GA, a trail was conducted to observe the response of freeze damaged 'Alapaha', 'Ochlocknee' and 'Powder Blue' rabbiteye blueberry flowers and fruit using treatments 1 and 3. The applications were with an air blast sprayer. The treatments were a complete block design with two blocks per cultivar. Four plants from each treatment had a single harvest where all fruit were removed and weighed for total harvest. From each treatment 50 ripe fruit weight was measured to identify average fruit weight. Application dates were 25 Mar. and 4 Apr.

Results

The first application, as the original experiment, was on 6 Mar. 2017 to both 'Brightwell' and 'Premier'. 'Brightwell' bloom was at 30% to 50% full bloom and 'Premier' was 60% to past petal fall (Fig 1). By 14 Mar., 2017, temperatures in the region dropped below freezing and freezing temperatures continued until the morning of 16 Mar. The freeze appeared to reduce crop load on the 'Brightwell' by 50% to 60% and 'Premier' lost 90% to 100% of the crop. By harvest, 'Premier' was a total loss. However, 'Brightwell' still had buds and tight clustered flowers that appeared to survive the freeze (Fig. 2). We continued with the experiment but modified it because 'Premier', as the focus of the study, had freeze damage to set fruit and flowers in bloom, plus little to no floral buds remained that did not appeared affected by the freeze (Fig. 2). We also included rabbiteye cultivars Alapaha, Ochlocknee, and Powder Blue

Fig. 1: 'Brighwell' at 30% to 50% bloom (left side of alley) and 'Premier' at 50 % to 90% bloom (right side of alley) on 6 Mar., 2017.

from the University of Georgia blueberry farm in Alapaha, GA in the revised experiment (Fig. 2).

Fig. 2: Photos of 'Premier', 'Brightwell', 'Alapaha', 'Ochlocknee', and 'Powder Blue' rabbiteye blueberries taken 24 Mar. 2017, eight days after freezing temperatures in south Georgia. This was the first application of GA_3; air blast application shown in Alapaha, GA.

Harvest

'Premier' was not harvested because fruit volume was low to non-existent throughout the treatments. 'Brightwell' was harvested on 7 Jun. (mature fruit) and 13 Jun (all remaining fruit). Harvest weights were significantly greater by 58% with GA_3 treated fruit when compared to GA_3+Soap. The 100 fruit weight of GA3+Soap treatment was 10% greater than the untreated fruit and the other fruit quality assessed were not significantly different for the 7 Jun. harvest. There were no significant differences measured for the 13 Jun. harvest of 'Brightwell' (Table 1). 'Alapaha' and 'Ochlocknee' harvests were on 22 Jun. and 29 Jun., respectively. There were no significant differences measured for both cultivars (Table 2). 'Powder Blue' was harvested on 22 Jun. and the untreated total harvest weight was 39% greater than the treated fruit. This data suggests that GA_3+Soap were not mitigating freeze damaged floral tissue. For 'Brightwell', GA_3 applications only slightly improved yield, though not significantly, when comparing untreated fruit.

Table 1: 'Brightwell' fruit quality measured as total weight (g) of yield, 100 count fruit weight (g), average fruit weight (g; 100 fruit count /100), soluble solids/sugars/ % acids (titrated with 0.1 N NaOH to endpoint 8.2 pH), and pH of titrated solution. Harvests were on 7 Jun. and 13 Jun. 2017.

	Total wt (g)	100 wt (g)	Avg Fruit wt (g)	Soluble Solids	% Acid	pH
			June 7, 2017 'Brightwell' Harvest			
Untreated	1900 ab[z]	159 b	1.6 b	14.9 a	0.4 a	3.8 a
GA	2155 a	171 ab	1.7 ab	14.3 a	0.5 a	3.9 a
GA + Soap	1366 b	175 a	1.8 a	13.9 a	0.4 a	3.5 a
			June 13, 2017 'Brightwell' Harvest			
Untreated	484 a	141 a	1.4 a	12.7 a	0.5 a	3.5 a
GA	691 a	137 a	1.4 a	12.6 a	0.5 a	3.6 a

GA + Soap	476 a	144 a	1.4 a	12.7 a	0.6 a	3.6 a

[z] Means followed by a different letter within a column are significantly different at $P < 0.05$ according to Fisher's least significant difference (lsd) test.

Table 2: 'Ochlocknee', 'Powder Blue', and 'Alapaha' harvest yields as total weight (g) and average fruit weight (g; 50 fruit weight/50). 'Powder Blue' and 'Alapaha' harvest was on 22 Jun. 2017 and 'Ochlocknee' was 29 Jun. 2017.

	'Ochlocknee'		'Powder Blue'		'Alapaha'	
	Total wt (g)	Avg Fruit wt (g)	Total wt (g)	Avg Fruit wt (g)	Total wt (g)	Avg Fruit wt (g)
Untreated	1671 a[z]	1.7 a	2873 a	1.5 a	567 a	1.2 a
GA	1696 a	1.8 a	2069 b	1.5 a	508 a	1.3 a

[z] Means followed by a different letter within a column are significantly different at $P < 0.05$ according to Fisher's least significant difference (lsd) test.

Conclusions

The focus of the study to identify applications of GA_3 and coconut oil soap to 'Premier' and its effect on yield was not accomplished because of freezing temperatures in mid-March 2017. However, the revised experiments did suggest that 250 ppm GA_3 with 5% (v/v) coconut oil soap inhibits yield and may not mitigate freeze damaged rabbiteye blueberry flowers and fruit. The application of GA_3 did not significantly improve yield for the cultivars tested, which suggest the use of GA_3 may not return the investment of purchasing and applying the product after a freezing event. Further, research is needed to identify the impact of GA_3 and coconut oil soap on production of 'Premier' without freeze damage.

Impact:

Applying GA_3 to freeze damaged rabbiteye blueberry flowers and fruit did not significantly improve yield in our trials. This suggests that the use of GA_3 with or without coconut oil soap may not have a return to the investment for labor, chemistries, and equipment use. Each application of GA_3 may cost the grower approximately $30.00 per acre for a 250 ppm application. Two applications over 10 acres would be $600.00 per season. If growers have experienced a freezing event that has damaged floral organs and set fruit, possibly the best response is to avoid GA_3 applications.

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