Title: Modifying cane architecture of primocane-fruiting blackberry with prohexadione calcium and summer pruning

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Project Category: Production Research – Production Efficiency and Profitability

Introduction:

Primocane growth management of blackberry by commercial growers relies on summer pruning/tipping primocanes at multiple heights throughout the growing season. Tipping can increase lateral branch development, bearing surface, and subsequent yields (Fernandez et al., 2016; Strik et al., 2012). However, tipping is a labor intensive and expensive process (~$600 per acre) that increases risk of cane blight infection. Cane blight (caused by *Leptosphaeria coniothyrium)* can result in mortality of fruiting canes and/or severe economic losses in the southeastern US (Brannen and Krewer, 2012). If effective, chemical management of blackberry primocane growth could reduce labor inputs associated with manual summer pruning/tipping, reduce incidence of cane blight due to manual summer pruning, and reduce the number of fungicide applications for managing cane blight. We investigated use of a plant growth regulator, prohexadione calcium (P-Ca), as an alternative growth management strategy of primocane-fruiting blackberry.

In other Rosaceous fruit crops, such as apple, P-Ca programs are commonly used to manage vegetative growth throughout the course of the growing season. P-Ca reduces terminal growth by inhibiting the synthesis of gibberellins, a group of endogenous hormones that contribute to the regulation of terminal shoot growth. Once applied, P-Ca requires between 10 and 14 days to slow growth. P-Ca degrades within the plant in a few weeks, and repeated applications are necessary to manage shoot growth throughout the growing season. As an example, for season-long growth control in apple, rates (62.5 ppm to 250 ppm) and number of applications (4 to 7 per year) vary to compensate for tree vigor (influenced by cultivar, rootstock, crop load, etc.).

While research with P-Ca on *Rubus* has been limited, initial results appear promising. Two applications of P-Ca resulted a 35 to 50 % reduction in primocane height of two floricane-fruiting blackberry cultivars when compared to an untreated control (Milivojević et al., 2017). P-Ca reduced internode length (42 to 55%) and cane diameter (~15%), but increased the number of lateral branches (13 to 24%). Lateral branch development is particularly important in blackberry, since yield is positively correlated with the lateral branch number (Strik et al., 2012). Increased lateral branch development resulted in a 21 to 27 % increase in yield with P-Ca (Milivojević et al., 2017). Similar effects on primocane growth and yield responses were observed in the floricane-fruiting raspberry cultivar ‘Willamette’ (Poledica et al., 2012). Fruit weight and fruit drupelet number from P-Ca treated canes increased by 8 to 19% and 5 to 17%, respectively (Milivojević et al., 2017). Increased fruit soluble solids concentration and reduced fruit acidity was observed with P-Ca treatment. P-Ca increased (Poledica et al., 2012) or had no effect (Milivojević et al., 2017) on total anthocyanins and total phenolic content. P-Ca effects on post-harvest life was not quantified in any of these experiments.

In 2018, PI’s Kon, Fernandez, Perkins, and Blaedow, initiated an experiment to determine the effects of P-Ca on primocane growth, yield, and fruit quality of floricane-fruiting ‘Osage’ and ‘Von’ blackberry. Three applications of 200 ppm P-Ca reduced primocane height by ~25% in ‘Osage’ and ‘Von’, respectively. Visual differences in primocane internode length and lateral branching were apparent (Fig. 1).

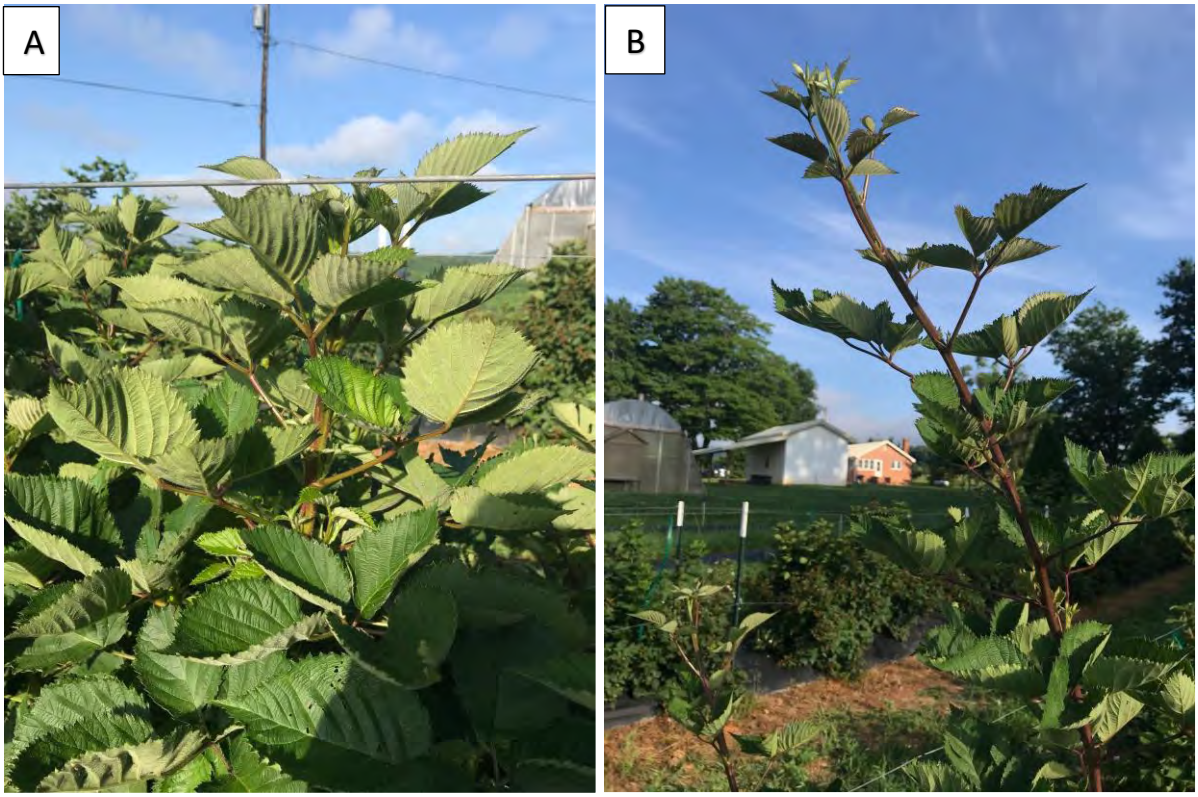

Fig 1. P-Ca treated primocane (A) and an untreated primocane (B). Internodal distance and lateral branch development appear to be influenced by P-Ca.

To our knowledge, P-Ca has not been evaluated on primocane-fruiting blackberry. On primocane-fruiting red raspberry, Palonen and Mohu (2009) demonstrated that P-Ca was effective in reducing cane height, but flower number per cane was reduced. The authors suggested that gibberellins in shoot tips may be associated with flower induction of priomocane-fruiting raspberry, and use of a gibberellin synthesis inhibitor may partly explain the reduction in flower number. The aforementioned trial was conducted on potted plants in the greenhouse environment and was terminated prior to fruit development. Given the limited data available, additional study is warranted.

Objective: Compare effects of primocane growth management strategies on cane architecture, reproductive development, and fruit quality of 'Traveler' blackberry.

Methods: The experiment was conducted in a three year-old 'Prim-Ark Traveler' blackberry planting at NC State University's Mountain Horticultural Crops Research and Extension Center in Mills River, NC (latitude 35.42721°, longitude -82.55888°). This site is 2,069' in elevation, soils are classified as Bradson gravelly loam, and average annual rainfall is 45". For three years prior to planting, the site was planted to soybeans (2016), cotton (2015), and vegetables (2014). Eighteen uniform plants were selected, flagged, and treatments were assigned in a randomized complete block design. The following treatments were evaluated:

1) untreated control,

2) tipping at ~ 46 cm and ~91 cm plant height, and
3) 200 pm P-Ca + 0.125% (v:v) non-ionic surfactant.

P-Ca treatments were applied using a CO_2 sprayer when cane height is ~46 cm. P-Ca will be applied at ~3 week intervals, until flower bud development is observed. For the tipping treatment, canes were soft-tipped when cane height is 46 cm and 91 cm.

Primocane height was measured at ~3 week intervals throughout the growing season. When fruit reach a commercially acceptable level of maturity, plots were harvested twice per week for six consecutive weeks. Marketable yield, unmarketable yield, and average fruit weight was determined. A 10 fruit subsample across two peak harvest dates was collected and frozen to quantify drupelet set, unset ovules, and total ovule number.

We planned to quantify post-harvest life and fruit composition, but there was insufficient fruit numbers to conduct this analysis.

After harvest, a morphometric characterization of three primocanes per plot occurred. Canes were cut at the base and moved to the lab for analysis. Basal cane cross-sectional area was determined, and number of fruiting nodes per cane were counted. The number of lateral branches per cane were counted. On each lateral branch, nodes were counted and length was measured. Leaves were excised and leaf area per cane was determined with a leaf area meter. Fresh and dry weight of each tissue type (cane, lateral branches, leaves) was determined.

The experiment had a randomized complete block design with six replications. The PC version of SAS (version 9.4; SAS Institute, Cary, NC) was used to carry out all statistical analysis. Analysis of variance was performed and Tukey's honest significance test in PROC MIXED was used to test mean separation among treatments at $P = 0.05$.

Results:

Vegetative growth of primocanes. Visible effects of P-Ca on primocane height were apparent within 14 days of the initial application and a significant reduction in height (25% reduction) was observed 21 d after treatment (Figure 2). With the rate and timings evaluated, this height reduction is similar to previous work with floricane-fruiting blackberry (Kon et al., 2019). P-Ca application did not occur until primocane height was ~56 cm. Based on responses in other cropping systems, starting P-Ca applications earlier in the season may result in a greater reduction in primocane height. While tipping resulted in a similar reduction in plant height early in the growing season, the effect was ephemeral. By mid-July there was no difference in primocane height between tipped and untreated plots.

Cumulative, marketable, and cull yield did not differ among treatments (Table 1). This was surprising, as tipping was demonstrated to increase lateral branching and subsequent yields (Fernandez et al., 2016; Strik et al., 2012). Perhaps the timing and/or frequency of tipping was inadequate to increase lateral branching and yield in 'Prim-Ark Traveler'. Milivojević et al. (2017) observed an increase in yield with P-Ca treatment on floricane-fruiting blackberry, but P-Ca was applied with a less aggressive application pattern than in the current study. While both strategies to manage vegetative growth did not differ from an untreated control, we observed a

lower numerical trend of productivity. Yields of floricane culivars in the same plot had approximately twice the yield of 'Prim-Ark Traveler'. These observations highlight the continued need to identify effective and consistent strategies that promote lateral branching and productivity of primocane-fruiting cultivars.

Morphometric characterization of floricanes. Multiple authors observed a reduction in basal cane diameter with P-Ca treatment (Milivojević et al., 2017; Palonen and Mouhu, 2009; Poledica et al., 2012), but P-Ca did not influence basal cane diameter in this experiment (Table 2). The reason for this difference is unclear. We observed no effect on basal cane diameter in two floricane-fruiting blackberry cultivars in the southeast US (Kon et al., 2019).

There were no differences in primocane leaf area, flower number, flower density (flowers per unit cm^2 cane cross-sectional area), and lateral branching among treatments. Palonen and Mouhu (2009) observed that P-Ca was reduced flower number per cane. The authors suggested that gibberellins in shoot tips may be associated with flower induction of priomocane-fruiting raspberry, and use of a gibberellin synthesis inhibitor may partly explain the reduction in flower number. While not significantly different, P-Ca treated canes trended toward lower flower density. Lateral branching was not influenced by tipping or P-Ca. In other studies, an increase in the number of fruiting laterals of floricane-fruiting blackberry was observed with tipping (Strick et al., 2012) and P-Ca (Milivojević et al., 2017). Treatment timings and/or application patterns of these vegetative growth management practices may have influenced efficacy. Alternatively, 'Prim-Ark Traveler' may need to be managed differently to enhance lateral branching and reproductive potential.

There were no differences in fresh and dry weights of primocane tissues (Table 3) and there is no evidence to suggest that tipping or P-Ca altered partitioning to aboveground vegetative structures of floricanes.

Conclusions:

While P-Ca shows promise as an alternative to reduce primocane height, this practice would likely need to be augmented with practices to enhance fruiting lateral number and subsequent productivity. This project was initiated due to the reported positive influence of P-Ca on floricane-fruiting blackberry in a European manuscript. Data from this trial did not accord with Milivojević et al. (2017) in many cases. While P-Ca application patterns could be refined to determine if negative impacts on yield can be avoided, continued evaluation of chemical and/or cultural practices to enhance lateral branch development and reproductive potential should also occur. Combinations of P-Ca and techniques to increase lateral branching would have merit in future research.

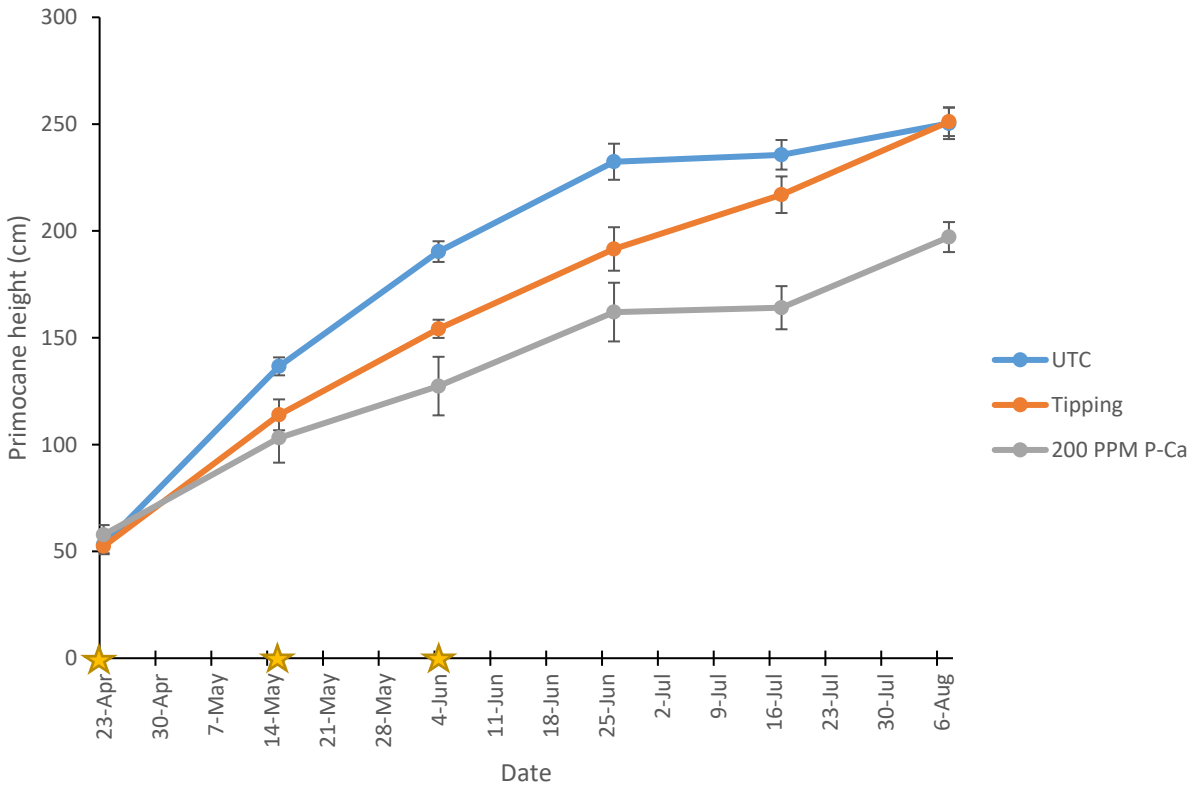

Figure 2. Comparison of primocane management strategies on primocane height of three-year-old 'Prim-Ark Traveler'. Stars represent application dates and error bars represent the standard error of the mean.

Table 1. Comparison of primocane management strategies on yield of three-year-old 'Prim-Ark Traveler'.

Treatment	Cumulative Yield (kg)		Marketable Yield (kg)		Cull Yield (kg)	
Control	2.2	NS	1.8	NS	0.5	NS
Tipping	1.6		1.3		0.3	
P-Ca	1.3		1.0		0.2	

Within column, mean separation by Tukey's (P = 0.05).

Table 2. Comparison of primocane management strategies on basal circumference, leaf area, flower number, and lateral branch characteristics of three-year-old 'Prim-Ark Traveler'.

Treatment	Circ. (cm)		Leaf Area		Flower (no.)		Flower no./ CSA		Laterals Count (no.)		Laterals Length (cm)		Laterals Node (no.)	
Control	4.3	NS	6651	NS	153	NS	92	NS	8	NS	58	NS	14	NS
Tipping	4.5		6826		161		102		8		61		15	
P-Ca	4.0		5246		98		75		7		51		12	

Within column, mean separation by Tukey's (P = 0.05).

Table 3. Comparison of primocane management strategies on fresh and dry weight of primcanes, laterals and leaves of three-year-old 'Prim-Ark Traveler'.

Treatment	Primocane Fresh Weight (kg)		Primocane Dry Weight (kg)		Laterals Fresh Weight (kg)		Laterals Dry Weight (kg)		Leaves Fresh Weight (kg)		Leaves Dry Weight (kg)	
Control	0.153	NS	0.066	NS	0.099	NS	0.048	NS	0.154	NS	0.062	NS
Tipping	0.160		0.070		0.101		0.046		0.156		0.062	
P-Ca	0.110		0.043		0.062		0.024		0.125		0.046	

Within column, mean separation by Tukey's (P = 0.05).

Appendix I.

Project Outputs

Conference Proceedings

1. Kon, T.M, G.E., Fernandez, P. Perkins-Veazie and K. Blaedow. 2019. Managing vigor of blackberry with prohexadione calcium: effects on primocane and floricane development. Acta Hort. *In press.*

Research Presentations:

1. Kon, T.M., G.E. Fernandez, P. Perkins-Veazie, and K. Blaedow. 2019. Managing vigor of blackberry with prohexadione calcium: effects on primocane and floricane development. XII International Rubus and Ribes Symposium, Zurich, Switzerland.
2. Clavet, C.D., T.M. Kon, G.E. Fernandez, P. Perkins-Veazie, and K. Blaedow. 2019. Managing vigor of blackberry with prohexadione calcium. Cumberland-Shenandoah Fruit Workers Conference, Winchester, VA

Extension Presentations

1. Kon, T.M, G.E., Fernandez, P. Perkins-Veazie and K. Blaedow. Short and stout: vegetative growth management of blackberry with pgr's. 09 Jan 2020. Southeast Regional Fruit and Vegetable Conference, Savannah, GA.
2. Kon, T. and G. Fernandez. Managing vigor of blackberry with prohexadione calcium. 13 Sep 2019. Annual NC Blackberry Field Day, Mountain Horticultural Crops Research and Extension Center, Mills River, NC
3. Kon, T. Managing vigor of blackberry with prohexadione calcium. 06 Feb 2019. Western District Winter Apple and Small Fruit School, Hendersonville, NC
4. Fernandez, G. Modifying cane architecture of primocane-fruiting blackberry with prohexadione calcium. 10 Jan 2019. Southeast Regional Fruit and Vegetable Conference, Savannah, GA.

References Cited:

Brannen, P.M. and G.W. Krewer. 2012. Cane blight of blackberry. University of Georgia Cooperative Extension. Circular 894.

Fernandez, G.E., E. Garcia, and D. Lockwood. 2016. Southeast Caneberry Production Guide. Southern Region Small Fruit Consortium. NC Cooperative Extension Service. AG-697. https://rubus.ces.ncsu.edu/spotlight/caneberry-production-guide/.

Kon, T.M, G.E., Fernandez, P. Perkins-Veazie and K. Blaedow. 2019. Managing vigor of blackberry with prohexadione calcium: effects on primocane and floricane development. Acta Hort. *In press.*

Milivojević, J., D. Radivojevic, J. Dragišić Maksimović, R. Veberić, and M. Mikulic-Petkovsek. 2017. Does plant growth and yield affected by prohexadione ca cause changes in chemical fruit composition of 'Loch Ness' and 'Triple Crown' blackberries. Eur. J. Hort. Sci. 82(4): 190-197.

Palonen, P. and K. Mouhu. 2009. Vegetative growth and flowering of primocane raspberry 'Ariadne' as affected by prohexadione-calcium treatments. HortScience 44(2):529-531.

Poledica, M.M., J.M. Milivojević, D.D. Radivojevic, J.J. Dragišić Maksimović. 2012. Prohexadione-Ca and young cane removal treatments control growth, productivity, and fruit quality of the Willamette raspberry. Turk. J. Agric. 36: 680-687.

Strik, B.C., J.R. Clark, C.E. Finn, and G. Buller. 2012. Management of primocane-fruiting blackberry: impacts on yield, fruiting season, and cane architecture. HortScience 47(5):593-598.