AGRICULTURAL RESEARCH FOUNDATION
FINAL REPORT
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TITLE: Targeted applications of calcium to berry fruit increase firmness for fresh and processed markets

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SUMMARY: The farm gate value of berry fruit (e.g. blueberry, raspberry, blackberry, and strawberry) for fresh and processed markets has increased considerably in Oregon in the last ten years. Growers need to produce high-quality fruit that has the maximum possible shelf-life (storage) to be competitive in the market place. Fruit firmness is highly correlated with shelf-life within berry crop type. Fruit firmness is also important for high-quality individually quick frozen (IQF) fruit when machine harvesting.

There is evidence in other crops that fruit calcium concentration (%Ca) is related to fruit firmness. Applications of liquid Ca formulations (usually Ca chloride or Ca nitrate) are common in apple production. The fruit %Ca in apple is often used to make decisions on expected storage life. In kiwifruit, pre-harvest Ca sprays to fruit have increased storage life (Gerasopoulos and Drogoudi, 2005). Penetration of Ca into fruit likely occurs through the stomata (pores) on the fruit surface. Penetration rates, however, have been shown to vary with cultivar, application method, and formulation of Ca used (Saure, 2005).

Growers have long been interested in nutrient management programs that increase fruit calcium with the objective of improving fruit quality. There are many foliar nutrient products available that contain Ca and many companies show increased leaf Ca levels as an indicator of product effectiveness. However, increased leaf Ca is not correlated with increased fruit Ca, as calcium does not move from the leaves to the fruit in plants. Past research in our program has shown that cultivars differ in the %Ca of ripe fruit even when they are all fertilized the same, and some cultivars (i.e. Draper) have high leaf Ca but low fruit Ca relative to other cultivars (Strik and Vance, 2015). Direct applications of Ca to fruit have been shown to increase fruit Ca in many crops, often with increased fruit firmness, storage life, and sometimes with reduced incidence of disease. In the berry industries, however, while growers use "foliar" Ca applications, no one has targeted fruit for Ca application.

OBJECTIVES:

- Evaluate different formulations of liquid Ca products for their effectiveness at increasing fruit Ca
- Assess whether increased fruit Ca will improve fruit quality in blueberry, raspberry, blackberry, and strawberry
- Determine if method of application impacts fruit Ca and quality (tested in blueberry only).

PROCEDURES: Two experiments were conducted, the first to study the impact of Ca formulation on several berry crops and cultivars and the second to study the effect of method of application.

Experiment 1

The trial was conducted at two commercial farms (location 1: Cornelius, OR; location 2: Salem, OR). Treatments were applied to commonly grown cultivars of each berry type (Strawberry: 'Hood' and 'Albion'; Blackberry: 'Obsidian' and 'Triple Crown'; Raspberry: 'Tulameen' and 'Vintage'; Blueberry: 'Draper', 'Liberty', 'Legacy', and 'Spartan'), representing early and later fruiting seasons. Five commercially-available Ca "foliar" products were evaluated at each location (Table 1).

Treatments were applied with backpack sprayers pressurized to approximately 60 psi and fitted with TeeJet 80-02 EVS brass nozzles. Treatment applications began at the late bloom to early green fruit stage for each cultivar with the number of applications varying with the length of fruit development (fruit set to harvest period) for each berry crop and cultivar. Preliminary results from early-season cultivars showed few differences among Ca treatments, so water volume was reduced to increase Ca concentration in later-season cultivars (Table 2).

Experiment 2

The trial was conducted in a certified organic planting of 'Draper' and 'Legacy' blueberry at the North Willamette Research and Extension Center (location 3). One Ca product (calcium chloride) was applied at the low rate (1.9 qts/acre) (Table 2) using either a backpack sprayer (as previously described) at a concentration of 0.05% Ca (80 gal/acre of water) or at a concentration of 0.16% Ca using an electrostatic sprayer (23 gal/acre of water) with two vertical booms each consisting of 13 nozzles.

Fruit harvest, tissue analysis, and storage

In each experiment, fruit were harvested at a commercial stage of ripeness. Ripe fruit were harvested on one date from 1 to 4 weeks after the final treatment application and were hand-picked directly into commercial polyethylene containers ("clamshells") of standard size for each crop. On the day of fruit harvest, a leaf tissue sample (most recent, fully-expanded leaves) was collected for nutrient analysis per plot. One clamshell of fruit from each treatment plot was randomly selected for nutrient analysis. Strawberry and blueberry fruit were washed with distilled water and excess water shaken off prior to shipping while raspberry and blackberry fruit were not washed (to maintain fruit integrity).

Data collected on the day of fruit harvest included berry weight, rating of fruit appearance, rating of flavor after rinsing, firmness, skin toughness, and total soluble solids (Brix; TSS). Additional clamshells were kept in a walk-in cooler to determine the impact of treatments on fruit storage ("shelf life"). Percent moisture, firmness, skin toughness, and TSS were measured at each of the storage times [5 and 10 days (all berry types) and 15 and 20 days (blueberry only)]. Due to insufficient harvested fruit of 'Hood', TSS was only measured at harvest and firmness was not measured. 'Draper' at location 2 was only sampled for lab analysis of Ca concentration; insufficient fruit were available for determination of quality at harvest and shelf-life.

SIGNIFICANT ACCOMPLISHMENTS:

Experiment 1

Targeted Ca applications did not impact leaf Ca at time of fruit harvest or fruit Ca concentration in any crop or cultivar (Table 3), nor were any changes in visual appearance or flavor of fruit detected at harvest (data not shown). Although a risk of phytotoxicity is mentioned in the literature, particularly when using Ca chloride (Chang et al., 2004; Cheour et al., 1990; Morris et al., 1980), we saw no evidence of fruit or leaf damage even at the highest concentration used (0.3% Ca chloride) in 'Albion'.

There was no effect of Ca treatment on visual ratings of decay and nesting during storage for any crop/cultivar (data not shown) so the data were pooled. In strawberry, fruit quality parameters, including firmness, skin toughness, berry weight or TSS were not affected by Ca applications. As expected, strawberry fruit lost more moisture as storage time increased. Interactions between cultivar and days of storage were found for percent moisture loss ($P < 0.0001$) and skin toughness ($P = 0.0010$) (Fig.1A and B). There was no difference in TSS at harvest between the cultivars studied (Fig. 1C). In 'Albion', firmness increased significantly between time of harvest and 10 d post-harvest ($P < 0.0001$) (Fig. 1D) while TSS was not impacted by storage time.

The few changes that were detected in raspberry fruit quality during storage were not consistent by treatment or cultivar; there was no effect of Ca treatment on any fruit quality parameter measured (data not shown). Interactions were found between cultivar and days of storage for percent moisture loss ($P < 0.0001$), skin toughness ($P < 0.0001$), firmness ($P < 0.0001$), and TSS ($P < 0.0001$) (Fig. 1A-D). 'Vintage' fruit may have had a greater percent moisture loss than 'Tulameen' because clamshells were not filled completely, leaving more airspace – a result of fewer ripe fruit available per plot at harvest. This also may have impacted firmness and skin toughness.

In blackberry, no effects of Ca treatment on fruit quality were seen (data not shown). TSS was only affected by cultivar ($P < 0.0001$) (Fig. 1C), while percent moisture loss was affected by both cultivar ($P = 0.0003$) and days of storage ($P < 0.0001$) (Fig. 1A). There was an interaction between cultivar and days of storage on skin toughness ($P < 0.0001$) and firmness ($P < 0.0001$). While 'Triple Crown' had higher skin toughness than 'Obsidian' (Fig. 1B), it was less firm at harvest and throughout storage (Fig. 1D).

Fruit quality and shelf-life were not affected by the foliar Ca treatment applications in blueberry (data not shown). In general, all fruit samples stored well with little decay. There was insufficient ripe fruit of 'Draper' at location 2 to assess fruit quality and shelf-life, though 'Draper' from location 3 had the firmest fruit and tough skin of any blueberry cultivar tested. There was an interaction between cultivar and days of storage for percent moisture loss ($P < 0.0001$), skin toughness ($P < 0.0001$), and firmness ($P < 0.0001$) (Fig. 2A-C), while TSS was not impacted by cultivar or storage time (Fig. 2D). 'Liberty' fruit were picked at a more advanced stage of fruit maturity at location 1 compared to location 2, perhaps explaining why 'Liberty' at location 2 had higher skin toughness and firmness. 'Spartan' had lower skin toughness and firmness than the other cultivars, demonstrating that it may be less suited to long-term storage for fresh market. 'Legacy' from Experiment 2 had among the lowest skin toughness and moderate firmness (Fig. 2B and C). 'Draper' had among the lowest fruit Ca (Table 5), but the highest fruit firmness, which suggests the relationship between fruit Ca and firmness may vary by cultivar.

Experiment 2

Method of application and the corresponding difference in Ca concentration applied (Table 2) did not impact fruit or leaf Ca concentration (Table 4), or any aspect of fruit quality or shelf-life (data not shown). Since the use of electrostatic sprayers is meant to improve coverage by spraying a mist of charged droplets that wrap around and adhere to all leaf and berry surfaces (Law, 1983), it was expected that Ca concentration would increase more than when using a backpack sprayer with larger, uncharged droplets primarily reaching the outer surfaces of the plant. Lower volumes of both water and product applied can often be used with electrostatic sprayers to achieve similar or better results compared to conventional air blast sprayers (Law and Scherm, 2005). However, since no formulation or concentration of Ca was successful at increasing fruit or leaf Ca in experiment 1, there may be other factors preventing the movement of Ca into the plants even with improved leaf and fruit coverage from the electrostatic sprayer.

Summary

Targeted calcium applications at the current label rates for the products used (0.05-0.30% Ca, depending on product and volume of water applied per hectare) were not effective at increasing fruit or leaf Ca concentration or altering fruit quality at harvest and during storage. Method of application also did not impact Ca concentration or fruit quality in blueberry. Aspects of fruit quality and shelf-life were dependent on cultivar.

BENEFITS & IMPACT:

While we found no positive effect of foliar applications at label rates of the various products growers use, this study has significant impact – we can, with confidence, inform growers that using label rates of these products is a waste of money. We have also shown that the method of application did not change the effectiveness of these foliar products or their ability to penetrate the leaves and fruit of berry crops, and provided some information about the impact of cultivar on shelf-life and changes in fruit quality during storage.

ADDITIONAL FUNDING RECEIVED DURING PROJECT TERM:

Oregon Blueberry Commission, Oregon Raspberry and Blackberry Commission, Oregon Strawberry Commission, Washington Blueberry Commission. In Kind Contributions: OnTarget Spray Systems

FUTURE FUNDING POSSIBILITIES:

No future funding is being solicited for this project.

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Table 1: Calcium treatments and label recommendations

Treatment number and "name"	Calcium formulation	Product name	Rate applied	Label recommendation
1. "control"	Water-control	water	0	n/a (only water applied)
2. "Ca-Cl Low"	$CaCl_2$	Phyta-Cal QC™ (8% Ca)	4.8oz Ca/A (136g/A)	2-4 quarts/acre
3. "Ca-Cl High"	$CaCl_2$	Phyta-Cal QC™ (8% Ca)	9.6oz Ca/A (272g/A)	2-4 quarts/acre
4. "Ca-B"	$CaCl_2$	Phyta-Set QC™ (6% Ca; 1% B)	4.8oz Ca/A (136g/A)	2-4 quarts/acre
5. "Ca-chelate"	$CaCO_3$ (chelated with citric acid)	Biomin Calcium (5% Ca)	4.8oz Ca/A (136g/A)	1-3 quarts/acre
6. "Ca-Silicate"	Ca_2O_4Si	Mainstay Calcium SI (10% Ca)	4.8oz Ca/A (136g/A)	1/2 -1quart (in 10-50gal water/acre) 1.25-2.25 quarts/acre (in 50+ gal water/acre)
7. "Ca-acetate"	$C_4H_6CaO_4$ (Ca acetate)	Cultivace Growth CaAce (5% Ca)	4.8oz Ca/A (136g/A)	1-3 quarts/acre

*****Higher concentration shown for Ca-Cl low when used in electrostatic sprayer at 23 gal/acre. All others are shown for application of 80 gal/acre.

Table 2: Calcium concentrations applied to berry crop cultivars

Product Name	Rate Applied (qts per acre)	% Ca applied in water (80 gal/acre): Obsidian, Tulameen, Spartan, Draper, Liberty, Legacy	% Ca applied in water (50 gal/acre): Hood, Triple Crown, Vintage	% Ca applied in water (25 gal/acre): Albion	% Ca applied in water (23 gal/acre): Electrostatic sprayer
Phyta-Cal QC (low)	1.9	0.05	0.08	0.15	0.16
Phyta-Cal QC (high)	3.8	0.09	0.15	0.30	n/a
Phyta-Set QC	2.5	0.05	0.08	0.15	n/a
Mainstay	1.5	0.05	0.08	0.15	n/a
Biomin-Ca	3	0.05	0.08	0.15	n/a
Cal-Ace	3	0.05	0.08	0.15	n/a

Table 3. Fruit and leaf calcium (Ca; %) at time of fruit harvest by treatment, crop, and cultivar for experiment 1 at location 1 (Cornelius, OR) and 2 (Salem, OR). From Vance et al. (in progress)

	Strawberry				**Raspberry**				**Blackberry**				**Blueberry (Location 1)**				**Blueberry (Location 2)**			
	‘Hood’		**‘Albion’**		**‘Tulameen’**		**‘Vintage’**		**‘Obsidian’**		**‘Triple Crown’**		**‘Spartan’**		**‘Liberty’**		**‘Liberty’**		**‘Draper’**	
Treatment	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf
Ca chloride (low)	0.11	0.78	0.18	2.12	0.14	1.63	0.19	1.77	0.16	0.53	0.32	1.28	0.02	1.61	0.05	0.63	0.05	0.59	0.05	0.81
Ca chloride (high)	0.10	0.80	0.17	2.12	0.14	1.78	0.22	1.80	0.15	0.51	0.27	1.39	0.02	1.86	0.06	0.59	0.05	0.62	0.05	0.89
Ca chloride+boron	0.10	0.78	0.18	2.36	0.14	1.73	0.23	1.77	0.15	0.52	0.28	1.20	0.02	1.55	0.05	0.57	0.05	0.62	0.05	0.86
Ca silicate	0.10	0.75	0.18	2.35	0.14	1.69	0.23	1.83	0.16	0.52	0.32	1.36	0.03	1.73	0.05	0.58	0.05	0.61	0.06	0.90
Ca chelate	0.10	0.80	0.15	2.43	0.14	1.70	0.21	1.88	0.15	0.47	0.31	1.32	0.02	1.73	0.05	0.60	0.05	0.63	0.05	0.88
Ca acetate	0.10	0.74	0.16	2.19	0.17	1.52	0.25	1.85	0.16	0.49	0.30	1.25	0.04	1.75	0.05	0.58	0.04	0.65	0.05	0.86
Control (water)	0.11	0.81	0.16	2.12	0.13	1.73	0.20	1.72	0.16	0.49	0.30	1.26	0.03	1.65	0.05	0.62	0.05	0.61	0.05	0.85
p-value[z]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[z]n.s. indicates not significant at P>0.05

Table 4. Fruit and leaf calcium (Ca; %) as impacted by cultivar and spray method in experiment 2 at the North Willamette Research and Extension Center (Aurora, OR). From Vance et al. (in progress)

	% Ca	
Treatment	Fruit	Leaf
Cultivar (CV)		
Draper	0.03	0.74
Legacy	0.05	0.54
Spray method (Sm)		
Backpack	0.04	0.64
Electrostatic	0.04	0.64
Significance[z]		
CV	0.0138	0.0176
Sm	n.s.	n.s.
CV x Sm	n.s.	n.s.

[z]P-value provided; n.s. indicates not significant at P>0.05

Figure 1. Impact of strawberry (‘Albion’, ‘Hood’), raspberry (‘Tulameen’, ‘Vintage’), and blackberry (‘Obsidian’, ‘Triple Crown’) cultivars on fruit percent moisture loss (**A**), skin toughness (**B**), total soluble solids, (%TSS) (**C**), and firmness (**D**) at 0 (day of harvest, no data for percent moisture loss), 5, and 10 d post-harvest at location 1 (Cornelius, OR), averaged over foliar calcium treatment (n = 28). From Vance et al. (in progress)

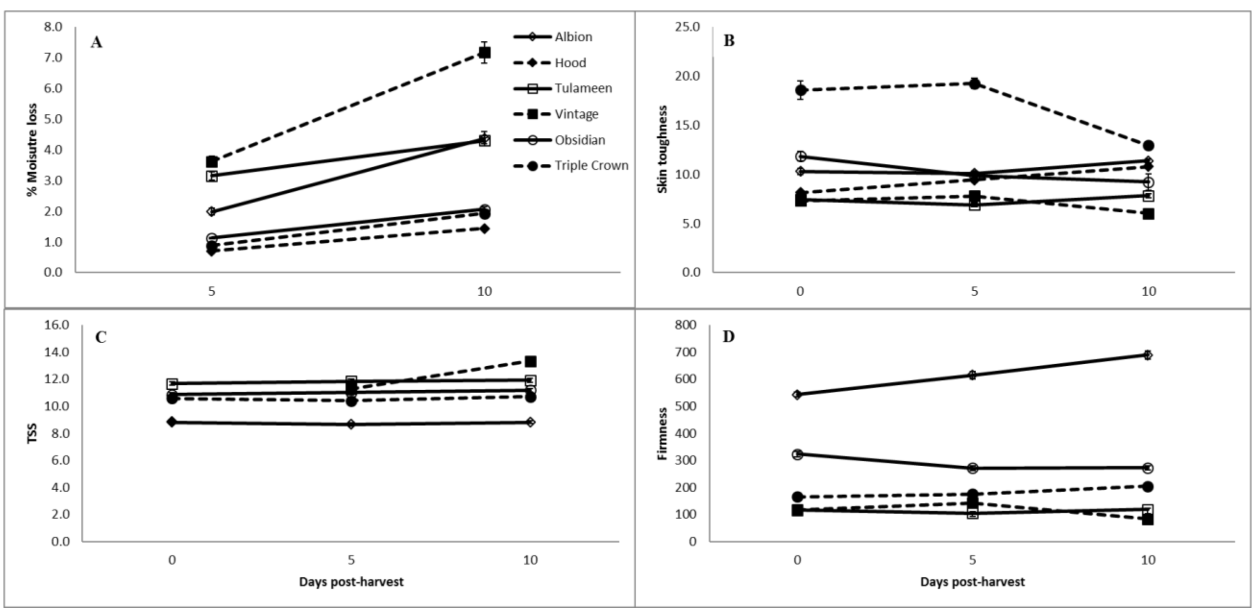

Figure 2. Impact of blueberry cultivars (‘Spartan’, ‘Draper’, ‘Liberty’, ‘Legacy’) in experiments 1 and 2 at location 1 (Cornelius, OR, n=28), 2 (Salem, OR, n=28), and 3 (North Willamette Research and Extension Center, Aurora, OR, n=4) on fruit percent moisture loss (**A**), skin toughness (**B**), total soluble solids (%TSS) (**C**), and firmness (**D**) at 0 (day of harvest, no data for percent moisture loss), 5, 10, 15, and 20 d post-harvest. Averaged over foliar calcium treatment at all locations and also over application method for experiment 2, location 3 (n=4). From Vance et al. (in progress)