EFFECTS OF CALCIUM SPRAYS AND AVG ON FRUIT QUALITY AT HARVEST AND AFTER STORAGE

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ABSTRACT

The goal of this project was to determine if foliar calcium sprays affect Bartlett pear fruit quality before or after storage. The following treatments were each applied to individual trees with a backpack mist blower: (1) Vigor-Cal + Agrobest® 9-24-3, 2-4 qts. each, 8 applications, (2) ReTain (AVG), applied once 2 weeks before harvest, (3) Treatments 1 & 2 combined, (4) calcium chloride, 4 applications, (5) soluble grade gypsum, and (6) untreated. Only calcium chloride increased July leaf Ca content, and no nutrient differences were found in the fruit. Few differences were seen in evaluations of fruit immediately after either harvest. Trees with black end were very vigorous and had elevated N, P, K, Ca, and Mg levels in the fruit. After both long-term storage and storage + ripening, fruit from treatments 1-4 held up better than untreated fruit or fruit treated with gypsum, both of which had significantly more scald and internal breakdown. In a separate orchard, calcium chloride was applied 5 times to 9 trees known to have black end, and another 9 black end trees were not treated. No differences in black end were found. Sampling of other black end trees found elevated N, P, K, Ca, and Mg, but also elevated levels of most of these nutrients in the soil.

INTRODUCTION

Preharvest nutritional status of fruit, especially with respect to calcium (Ca), is an important factor affecting potential storage life. Fruits with a high level of Ca have lower respiration rate and longer potential storage life than fruits containing low Ca (Fallahi et al., 1997; Li et al., 2005). Many physiological disorders in fruits are associated with Ca deficiency. The easiest way to maximize fruit Ca level is through a foliar spray. However, in some cases it is very difficult to achieve because of the restricted uptake and penetration of Ca into the fruit and its movement within fruit tissue (Mengel, 2002).

Increased Ca through three mid-summer calcium chloride ($CaCl_2$) sprays has been shown to reduce incidence of side rot (*Phialophora malorum*) in Bosc pears (Sugar et al. 1991). Lesion diameters of wound-inoculated fruit were also reduced by $CaCl_2$ spray treatments. The use of Ca sprays with low N led to a 50% reduction in blue mold (*Penicillium expansum*) compared to high-N blocks without $CaCl_2$ sprays.

AVG (ReTain™) is an ethylene biosynthesis inhibitor that is derived via fermenting the naturally occurring antibiotic rhizobitoxine. Fruit color and size may be enhanced by

allowing fruit to remain on the trees longer without adverse effects on storage life. This gives the product value in extending harvest if needed due to labor shortages.

AVG has shown more consistent effects on apple than on pear, partially because pears produce much less ethylene on the tree than apples, making spray timing more difficult (Elkins et al., 2012). AVG-treated apples have been shown to stay firmer, store longer, and develop less watercore than NAA-treated fruit, but in some instances AVG-treated fruit had slightly less sugar and color. Studies on pear have produced promising but inconsistent results, probably due in part to the trial locations; both the need for a stop-drop (NAA) spray and the uptake and action of a stop-drop may be influenced by environment (Elkins et al., 2012). In addition to reduced firmness loss, better green color retention and reduced internal browning have been reported.

A key factor in evaluating products is their cost effectiveness. A low product price and the ability to tank mix it with other applications makes it an attractive option. The grower price for Vigor-Cal is approx. $22/gal. and Agro-K 9-24-3 is $16/gal., so at 2 qts./acre each, the combined cost is about $19.00 per application, or $76 for 4 applications. There is no application cost since the products can be mixed with blight sprays.

The ReTain label states that data are not available on tank mixing with products (such as NAA) other than a few biological insecticides. However, testing in the North Coast has showed no compatibility problems (R. Elkins, personal communication). ReTain is applied at 11.7 oz. (one bag) per acre, which costs $265.

First Year Results. The 2013 trial used 5 treatments with 8 replicate trees. The treatments were: (1) Vigor-Cal + 9-24-3 at 2 qts./acre each, four weekly applications, (2) Vigor-Cal + 9-24-3 at 4 qts./acre each, four weekly applications, (3) ReTain alone 2 weeks before harvest, (4) Vigor-Cal + 9-24-3 at 4 qts./acre each and ReTain 2 weeks before harvest, (5) untreated control.

First-pick fruit were used for the fruit evaluations. Soluble solids were elevated in fruit treated with ReTain alone, and significantly higher after 7 days of ripening. Only after 7 days of ripening were there significant differences in fruit firmness: Fruit in the Vigor-Cal + 9-24-3/ReTain treatment had the highest pressure (about 0.5 lb. increase) and ReTain-only fruit were intermediate. After 6 weeks of storage, there was almost no scald or internal breakdown in any treatment. Another trial was needed to evaluate second-pick fruit, other products, and increased numbers of applications.

OBJECTIVES

1. Evaluate the effects of foliar calcium sprays and ReTain on fruit quality of Bartlett fruit at commercial harvest and after storage and ripening.

2. Further understand black end and determine if calcium sprays reduce the disorder.

PROCEDURES

The trial was conducted in a Bartlett orchard on Merritt Island in Sacramento County. A portion of the orchard was used in an area where black end was reported to occur. The experiment was set up as a randomized complete block design, with 6 treatments and 9 single-tree replicates. The following treatments were used:

1. Vigor-Cal + Agrobest 9-24-3
2. ReTain
3. Vigor-Cal + Agrobest 9-24-3 + ReTain
4. Calcium chloride ($CaCl_2$)
5. Soluble grade gypsum (Diamond K)
6. Untreated

Individual trees were separated by one guard tree and a full row on either side. Trees were sprayed with a rate of 100 gal./acre using a mist blower backpack sprayer, with the application dates and rates shown below.

Date	Products	Rate per Acre
3/19	Vigor-Cal + 9-24-3[1]	2 qts. each
3/24, 4/2, 4/8, 4/15, 4/22, 5/13, 6/3	Vigor-Cal + 9-24-3	4 qts. each
4/2, 4/8, 4/15, 4/22, 4/29, 5/13, 6/3	Soluble gypsum	8 lbs.
4/ 29, 5/13, 5/20	$CaCl_2$	1.8 lbs.
6/26	ReTain + NuFilm 17[2]	11.7 oz.

[1]9-24-3 (Agro-K) is included to help mobilize the Vigor-Cal in cold weather.
[2]NuFilm 17 is a sticking-extending adjuvant with non-ionic properties.

To determine how effectively the foliar spray nutrients are taken up by tissues, leaves and fruit were sampled and consolidated in each treatment for nutrient analysis. A total of 135 mid-shoot leaves and 90 fruit from each treatment were sampled in July. Leaves were immediately cooled and transported to the lab, then washed with water containing non-detergent soap, double rinsed, dried, and taken to the UCD Laboratory for analysis of N, P, K, and Ca.

Just prior to the first commercial harvest, five high fruit and five low fruit from each tree were randomly sampled (size-picked). Fruit weight, soluble solids content, and firmness were measured.

Just prior to the second harvest, 40 fruit per treatment replicate were taken to the UCD lab; 10 of the fruit were measured for fruit weight, soluble solids content, and firmness. The remaining fruit were cooled at 32°F and used for post-storage evaluation of storage disorders (scald and internal breakdown) after 3.5 months, with and without ripening.

Fruit russetting was also evaluated after storage.

In an orchard north of Walnut Grove, foliar Ca sprays were applied to nine Rosired pear trees that a previous study found consistently produced fruit with black end symptoms. Trees were sprayed with granular, orchard-grade $CaCl_2$ at a rate of 2 lbs./acre in 100 gal./acre water using a backpack mist sprayer. Sprays were applied 4/29, 5/7, 5/13, 5/20, and 6/3. Another nine black end trees were untreated. Fruit on each tree were rated for black end. In a different part of the same orchard, leaves and fruit (wedges) from two trees each of both Rosired and Red Sensation with and without black end were submitted to the UC Davis analytical lab for nutrient analysis, along with soil samples from under each tree.

RESULTS

Black end began to be visible in certain trees in the foliar Ca trial, and these trees were also found to be more vigorous than non-black-end trees. July leaf sampling showed that the black end trees had higher N and lower P and K (Table 1). Slightly elevated levels of P and K were found in untreated trees compared to those of treated trees, and Ca was higher in leaves of trees treated with $CaCl_2$. In the fruit analyses, no strong nutrient differences were seen among treated trees, but fruit of black-end trees had higher levels of N, P, K, Ca, and Mg (Table 2).

Immediately after harvest, no significant differences were found among treatments for fruit weight, soluble solid content, or firmness, but fruit from the Vigor-Cal + 9-24-3 + ReTain and $CaCl_2$ treatments were slightly but significantly greener than solution grade gypsum (Table 3). Postharvest data from fruit from black-end trees were omitted from the analyses. Immediately after the second pick there were no differences among treatments in any of the above quality measurements (Table 4).

After 15 weeks of storage of second-pick fruit, fruit treated with gypsum were significantly less firm than fruit of other sprayed trees, and fruit from untreated trees were lowest in firmness (Table 5). Similarly, fruit treated with gypsum were yellower than fruit of most other sprayed trees and fruit from untreated trees were yellowest; fruit from both these treatments had significantly more scald. After 4 days of ripening, fruit treated with gypsum and untreated fruit had more scald and internal breakdown than other treatments (Table 6). However, after storage + ripening, firmness trends reversed compared to firmness after storage alone; gypsum and untreated fruit were now firmer than fruit of other treatments. No differences in russetting were seen (data not shown).

In the black end spray trial near Walnut Grove, the number of fruit with black end on trees sprayed with $CaCl_2$ was not significantly different from that of unsprayed trees: the average number of black end fruit per 50 fruit was 17.2 on unsprayed trees and 15.1 on sprayed trees.

The soil sampled from the Rosired and Red Sensation trees on July 29 showed elevated levels of P, Ca, Mg, cation exchange capacity, and organic matter under the

black-end trees of both Rosired and Red Sensation compared to the soil under trees with no black end (Table 7). Similar higher levels were found in the leaves of black end trees for P, but not Ca and Mg (Table 8). High nitrate and low K found in the soil under the Rosired trees with no black end were reflected in higher N and lower K in the leaves of these trees. Analyses of fruit showed that P, Ca, Mg, and N were elevated in trees with black end and K was lower in the Rosired trees with no black end (Table 8).

DISCUSSION

In July, the only trees that showed elevated leaf Ca content were those treated with $CaCl_2$, and no nutrient differences were seen in the fruit. Few differences were seen in evaluations of fruit immediately after either harvest, although fruit on trees treated with gypsum were slightly yellower after the first pick. After long-term storage, fruit treated with Vigor-Cal + 9-24-3, ReTain, and $CaCl_2$ held up better than untreated fruit or fruit treated with gypsum. The greater firmness found in the untreated and gypsum-treated fruit after storage and ripening may have been a result of water loss from these deteriorating fruits. On stored and ripened fruits, scald and internal breakdown were also greatest for these two treatments, and no internal breakdown was found on fruits treated with Vigor-Cal + 9-24-3, ReTain, or $CaCl_2$. Raese (1993) found that stored fruit from Bartlett trees in Washington that received six $CaCl_2$ sprays were firmer and had less scald and internal browning, as well as less black end than unsprayed trees.

It appears that a major effect of foliar calcium sprays is to enable fruit to be held longer in storage. This effect was seen with two calcium products and pre-harvest ReTain, but not with gypsum. Calcium sprays applied through the spring had no effect on July leaf or fruit nutrient levels, with the exception of higher leaf Ca content in trees treated with $CaCl_2$.

Most Sacramento Delta growers who spray Vigor-Cal + 9-24-3 make about 3-4 applications in early spring using 2 qts. each. In this trial, the first spray was applied at 2 qts. and seven were applied at 4 qts. Agro-K recommends multiple applications through the spring and early summer. In 2013, four applications of 4 qts. were made and evaluations were made on size-picked fruit from the first pick; no scald or internal breakdown were found in any fruit. The 4-qt. rate used in the 2014 trial was used to see if there would be effects at higher application rate and more applications. Also, the largest second-pick fruit were used, since these later fruits are more likely to end up in storage than first-pick fruits. In addition, larger size-picked fruits were used from trees that were not harvested at the first pick.

In 2013, ReTain applied 2 weeks before harvest did not increase fruit firmness at the first pick, but firmness was reduced by 0.5 lb. after 1 wk. of storage. In 2014, no effects on firmness were seen immediately after either harvest. These results reflect the inconsistent effects seen with the use of ReTain in pears. ReTain is sometimes used on a portion of a grower's acreage in order to delay the firmness threshold for harvest and therefore to allow a delayed harvest due to labor shortages, and to increase storage life. These results suggest that firmness may not be affected, but storage life is improved.

Bartlett pears are usually sold relatively quickly, so long-term storage is not generally practiced. However, at times some factors may cause fruit to remain in storage, such as another country placing a large amount of stored pears on the market just before California harvest, or when market conditions are otherwise unfavorable. Improving storability is a good practice generally if the methods are cost-effective. Vigor-Cal and $CaCl_2$ are relatively inexpensive and can be applied with blight sprays. Although ReTain had little effect on fruit firmness, it did extend storage life. The cost-effectiveness of ReTain is considered highly questionable based on the results of this study.

Black end was found on seven of the 54 experimental trees, and these trees were excluded from harvest analyses. Each of the black end trees had very vigorous growth that was likely the result of a different rootstock such as Betulaefolia. Leaves from black end trees had higher N and lower P and K than other treatments, but fruit had higher N, P, K, Ca, and Mg content than the other treatments.

In the Walnut Grove orchard, fruit from black end Rosired and Red Sensation trees had higher N, P, K, Ca, and Mg, as in the foliar calcium trial, but also higher leaf P than trees with no black end. Black end trees at that site also had higher soil P, K, Ca, Mg, organic matter, and CEC than non-black end trees. It is unlikely that the black end in the Walnut Grove orchard was caused by an excess of nutrients since the levels observed are within a normal level and no available studies showed a relationship between high soil nutrient content and black end. It is unknown if the black end trees are on a different rootstock; these trees did not appear to be more vigorous than non-black end trees.

Literature Cited

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Table 1. Leaf nutrient analyses, sampled July 8. Leaves from all replicate trees were consolidated for each treatment. Black end trees were sampled separately.

Treatment	% N	% P	% K	% Ca
Vigor-Cal + 9-24-3	1.77	0.24	1.51	1.23
ReTain	1.88	0.25	1.62	1.32
Vigor-Cal + 9-24-3 + ReTain	1.85	0.24	1.66	1.27
$CaCl_2$	1.93	0.24	1.66	1.54
Solution grade gypsum	1.94	0.24	1.52	1.30
Untreated	1.88	0.29	1.76	1.30
Black end trees	2.05	0.19	1.46	1.30

Table 2. Fruit nutrient analyses, sampled July 14. Wedges of fruit from all replicate trees were consolidated for each treatment. Black end trees were sampled separately.

Treatment	% N	% P	% K	% Ca	% Mg
Vigor-Cal + 9-24-3	0.20	0.068	0.69	0.031	0.040
ReTain	0.23	0.073	0.75	0.033	0.041
Vigor-Cal + 9-24-3 + ReTain	0.23	0.074	0.77	0.032	0.043
$CaCl_2$	0.22	0.072	0.76	0.033	0.042
Solution grade gypsum	0.22	0.073	0.73	0.028	0.039
Untreated	0.25	0.080	0.79	0.035	0.044
Black end trees	0.37	0.090	0.90	0.042	0.053

Table 3. Postharvest quality evaluations of fruit immediately after the first pick (July 8, size picked to 2¾ in.[+]).

Treatment	Avg. Fruit Wt. (lb.)		Soluble Solids (%)		Color Rating (a*[C])[1]		Firmness (psi)	
Vigor-Cal + 9-24-3	0.41	ns[2]	12.9	ns	-19.1	ab	17.7	ns
ReTain	0.39	ns	12.2	ns	-19.1	ab	17.9	ns
Vigor-Cal + 9-24-3 + ReTain	0.40	ns	12.6	ns	-19.4	a	17.6	ns
$CaCl_2$	0.39	ns	12.3	ns	-19.3	a	17.2	ns
Solution grade gypsum	0.40	ns	12.5	ns	-18.8	b	17.9	ns
Untreated	0.40	ns	12.4	ns	-19.2	ab	17.6	ns
Treatment		*ns*		*ns*		*		*ns*
Rep		*ns*		*ns*		*		*ns*

[1]*Lower numbers (increasingly negative) indicate greener fruit.*
[2]*Means separation within columns by Duncan's MRT, *=0.5% level; ns=not significant.*

Table 4. Postharvest quality evaluations of fruit immediately after the second pick (July 15, size picked to 2¾ in.$^{+}$).

Treatment	Avg. Fruit Wt. (lb.)		Soluble Solids (%)		Color Rating (a*[C])[1]		Firmness (psi)	
Vigor-Cal + 9-24-3	0.45	ns[2]	12.4	ns	-18.4	ns	15.8	ns
ReTain	0.47	ns	12.5	ns	-18.9	ns	15.9	ns
Vigor-Cal + 9-24-3 + ReTain	0.47	ns	12.2	ns	-18.6	ns	15.9	ns
$CaCl_2$	0.45	ns	12.4	ns	-18.3	ns	15.4	ns
Solution grade gypsum	0.46	ns	12.2	ns	-18.5	ns	16.1	ns
Untreated	0.47	ns	12.3	ns	-18.6	ns	16.1	ns
Treatment		*ns*		*ns*		*ns*		*ns*
Rep		*ns*		*ns*		*ns*		*ns*

[1]*Lower numbers (increasingly negative) indicate greener fruit.*
[2]*Means separation within columns by Duncan's MRT, no significant differences.*

Table 5. Postharvest quality evaluations of second-pick fruit (July 15, size picked to 2¾ in.$^{+}$) after 15 weeks of storage and no ripening.

Treatment	Firmness (psi)		Color Rating (a*[C])[1]		% of Fruit with Scald	
Vigor-Cal + 9-24-3	13.5	a[2]	-8.46	ab	0.0	b
ReTain	13.8	a	-9.32	a	0.0	b
Vigor-Cal + 9-24-3 + ReTain	13.7	a	-8.91	a	0.0	b
$CaCl_2$	14.3	a	-7.28	bc	0.0	b
Solution grade gypsum	11.6	b	-6.56	c	35.8	a
Untreated	9.7	c	-5.20	d	28.6	a
Treatment		***		***		***
Rep		*ns*		*ns*		*ns*

[1]*Lower numbers (increasingly negative) indicate greener fruit.*
[2]*Means separation within columns by Duncan's MRT, ***=0.1% level; ns=not significant.*

Table 6. Postharvest fruit quality evaluations after 15 wks. storage and 4 days ripening.

Treatment	Firmness (psi)		Color Rating (a*[C])[1]		% of Fruit with Scald		IB[2] Score	
Vigor-Cal + 9-24-3	2.19	b[3]	-1.99	ns	10.8	b	0.0	b
ReTain	2.32	b	-2.59	ns	7.8	b	0.0	b
Vigor-Cal + 9-24-3 + ReTain	2.07	b	-1.76	ns	10.1	b	0.0	b
$CaCl_2$	2.13	b	-1.26	ns	4.8	b	0.0	b
Solution grade gypsum	3.29	a	-1.97	ns	61.0	a	0.60	a
Untreated	3.70	a	-1.57	ns	47.0	a	0.98	a
Treatment		**		*ns*		***		***
Rep		*ns*		*		*ns*		*ns*

[1]Lower numbers (increasingly negative) indicate greener fruit. [2]IB = Internal breakdown
*[3]Means separation within columns by Duncan's MRT, ***=0.1% level, **=1% level, and *=5% level; ns=not significant.*

Table 7. Soil nutrient analyses under good and black end (B.E.) trees of two varieties.

	NO3-N	Olsen-P	X[1]-K	X-Ca	X-Mg	CEC[2]	OM[3]
Variety	(ppm)		(meq/100g)				
Rosired (good)	10.7	27.3	0.56	16.5	9.2	26.6	3.4
Rosired (B.E.)	6.2	44.5	0.69	21.0	13.9	36.2	4.8
Red Sensation (good)	5.2	22.3	0.64	13.5	8.5	22.9	3.1
Red Sensation (B.E.)	7.5	38.1	0.70	22.2	12.6	35.9	4.6

[1]X=Exchangeable [1]CEC=Cation exchange capacity [1]OM=Organic matter

Table 8. Nutrient analyses of good and black end (B.E.) trees of two pear varieties.

	N	P	K	Ca	Mg
Variety	(%)				
	Leaves				
Rosired (good)	2.40	0.146	0.79	1.12	0.358
Rosired (B.E.)	2.32	0.179	1.12	1.51	0.363
Red Sensation (good)	2.25	0.140	1.15	1.57	0.372
Red Sensation (B.E.)	2.26	0.158	0.95	1.59	0.323
	Fruit				
Rosired (good)	0.36	0.058	0.59	0.028	0.035
Rosired (B.E.)	0.54	0.094	0.83	0.045	0.050
Red Sensation (good)	0.41	0.065	0.71	0.031	0.038
Red Sensation (B.E.)	0.52	0.088	0.81	0.042	0.047