Understanding the Increasing Black End Problem and the Potential for Foliar Calcium Sprays to Reduce It

Chuck Ingels and C. Gordon Card
UC Cooperative Extension, Sacramento County

Problem and its significance:

In recent years, a disease that appears to be black end has increased in several pear orchards in the Sacramento River district. According to Ogawa and English (1991), "black-end" or "hard-end" are names given to a pear fruit disorder in which the tissue of the calyx end of the ripe fruit is hard and dry and the pH of the tissue is high. The disorder is known to affect mainly trees on Asian rootstocks such as *Pyrus serotina*, *P. ussuriensis,* and *P. betulaefolia*, but not trees on rootstocks such as Winter Nelis and Old Home × Farmingdale (Raese 1994b). It was postulated to be caused by certain metabolites produced in Asian pear rootstocks and translocated to the fruit (Ryugo 1988). Black end was commonly seen before the 1960s, but since the far majority of trees on Asian rootstocks have since been removed due to pear decline, the disorder has become very rare. In recent years, however, the disorder is reappearing and seems to be increasing in some orchards that are largely on *P. communis* rootstocks.

One possible cause of black end is water stress (Ohlendorf 1999, Welsh 1979). Both water stress and poor drainage can kill or stunt roots and may send similar metabolites to the fruit as occurs with Asian rootstocks. Although in one study (Yamamoto and Watanabe 1983) no difference in water potential developed between normal and black end-affected trees, it was suggested that low fruit water intake during early to mid-season leads to fruit Ca deficiency in black end-affected Bartlett fruit.

There is reason to believe the disorder may be associated with poor drainage. In one Sacramento River district orchard (all trees were on Winter Nelis rootstock), the drainage system was broken during 2004 and black end was severe throughout the block. In another orchard (the Twin Cities orchard discussed below), the Rosired pears were severely affected for several years. In 2003, black end moved into the Bartlett trees and in 2004, a greater portion of the Bartlett trees was affected (these 30 to 40 year-old-trees have been determined to be on *P. betulaefolia* rootstock, but the disorder only recently appeared). Some pest control advisers report that black end is fairly widespread throughout the district, and is worse in some years than others.

There has been interest in determining whether or not calcium may play a role in black end, as it does in bitter pit of apple and blossom end rot of tomato. In 2003, whole fruit were analyzed by a testing lab (courtesy of Harvey Lyman, Inc.) for potassium and calcium and the results are shown in Table 1. The potassium content of peels of black end fruit was far higher than that of healthy fruit, whereas the calcium content was lower.

Table 1. Potassium and calcium content (ppm) of peel and flesh tissues of whole diseased and healthy fruits, sampled in July 2003.

	Potassium (K)		Calcium (Ca)		K/Ca Ratio	
	Peel	Flesh	Peel	Flesh	Peel	Flesh
Black end	3690	5640	740	430	5.0	13.1
Healthy	741	4290	1050	360	0.7	11.9

Wenatchee Study. A study of black end was conducted in Wenatchee, WA, using Bartlett trees on Bartlett seedling rootstocks (Raese 1994a). The trial orchard had subsoil hardpan and poor soil moisture conditions, which likely led to the black end problem. Nutrient analysis of fruit with black end compared to fruit without black end from the same tree showed that black end fruit had significantly lower calcium, magnesium, and manganese levels, but higher nitrogen and phosphorus than non-black end fruit. Surprisingly, fruit from trees having no black end were not always higher in fruit calcium than fruit from black end trees. Black end trees also had greater crop load but smaller fruit.

To attempt to control black end with calcium sprays, calcium chloride ($CaCl_2$ [36% Ca]) was applied at 1.8 lb./100 gal. six times from mid-May through late July in replicated blocks. The sprays increased the calcium content of the fruit peel and flesh. During the 4-year study, the number of black end fruit was reduced by an average of over 50 percent compared to unsprayed trees. In the fifth year, no sprays were applied and the previously sprayed trees had significantly more black end than the untreated trees. In the second year of the study (no results were published for the first year), the sprays resulted in higher calcium levels in the leaves (1.3%), and untreated trees without black end had higher calcium (1.2%) than black end trees (1.1%). The sprays did cause some fruit injury during the three treatment years.

Another pear study showed that Anjou fruit with several disorders, such as stony pit, green stain, alfalfa greening, cork spot, and black end, were lower in calcium than normal fruit (Raese 1984). The research showed that, in many cases, these disorders were reduced, but not eliminated, by calcium chloride ($CaCl_2$) sprays.

Objective 1: To determine the extent of the black end problem in the Sacramento River district and to identify factors associated with the disease.

Methods and Materials (Objective 1)

Growers and pest control advisers were contacted and asked where black end has appeared in recent years. Four orchards were identified, with variable amounts of black end. In these orchards, we sampled 75 leaves and 10 fruit each from of a total of 44 trees (22 with black end and 22 without) for nutrient analysis. We tested stem water potential on 10 trees in each of two orchards. We sampled soil in each orchards for nutrient analysis. We also characterized the black end and tried to identify rootstocks of trees in black end areas vs. trees in areas with no black end.

Results (Objective 1)

There were no differences in water potential between black end and no-black end trees (data not shown).

One orchard (southwest of Walnut Grove) had only a few trees in one area with black end; the second orchard (Merritt Island) had only one tree with black end, although the block had many trees with black end the previous season; the third orchard (Randall Island) had two areas with extensive black end, and the fourth orchard (Twin Cities Rd.) had one area with extensive black end and another area (the calcium trial area described later) in which the black end trees were random and intermittent.

On average, black end fruit had more nitrogen (N) and potassium (K) than fruit from trees in the same blocks with no black end (Figure 1). Calcium (Ca) and magnesium (Mg) levels were nearly identical. However, all leaf nutrient levels of trees with black end were very similar to those without black end (Figure 2).

Figure 1. Nutrient content of <u>fruit</u> with black end (BE) vs. fruit from trees with no black end, average of all orchards (10 fruit per tree, total of 44 trees) (Fisher's LSD, P>0.05).

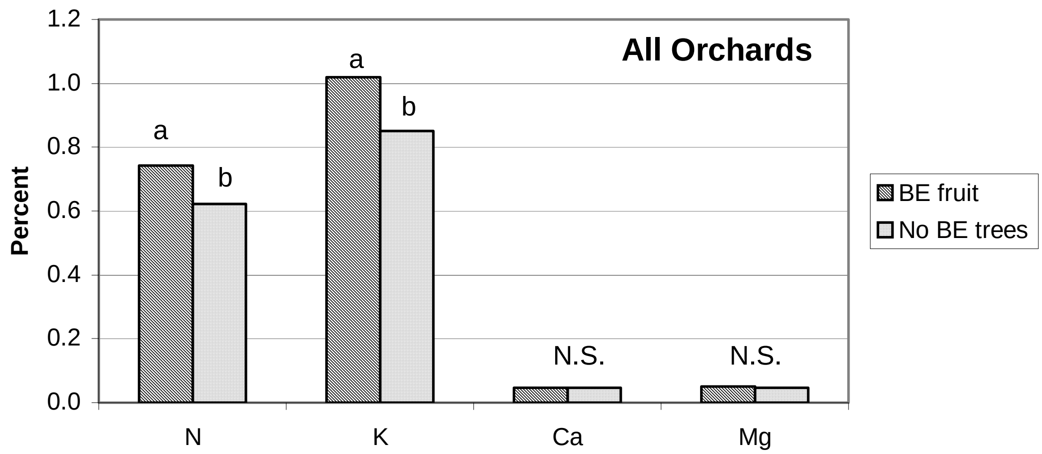
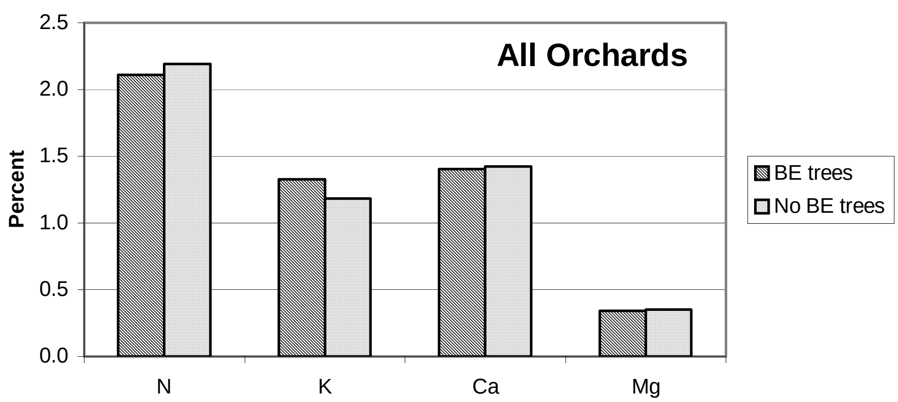


Figure 2. Nutrient content of <u>leaves</u> from trees with black end (BE) vs. leaves from trees with no black end, average of all orchards.



In the Randall Island orchard, portions of two adjacent blocks had a substantial amount of black end, but in one of these blocks, an area of about 40 to 50 trees had no black end. We tested leaves, fruit, and soil in these three areas. <u>Leaves</u> from trees in the area with no black end present had significantly more N, and significantly less K than trees in the black end areas (Figure 3). However, <u>fruit</u> from trees in the area with no black end had significantly less N and K than those from black end trees, and fruit from trees with no black end but within the black end area had intermediate N and K levels (Figure 4). The <u>soil</u> from the no-black end area had slightly more N and substantially more K than soil from the black end area (Figure 5). Therefore, although the soil from the area with no black end had much more K than the soil from the black end area, the reverse was true for both leaves and fruit. Trees with black end were able to take up far more K than trees without black end, which could indicate a rootstock effect.

In the Twin Cities orchard, soil nitrogen and potassium were slightly higher under the black end trees than under the trees with no black end (data not shown). Similarly, fruit from black end trees had significantly more N and K than trees with no black end (Figure 6), but no significant differences were found in leaf nutrient content (Figure 7).

Figure 3. Nutrient content of leaves from trees with black end, trees without black end but in an area with a large amount of black end, and trees in an adjacent area that had no black end present, Randall Island orchard (Fisher's LSD, P>0.05).

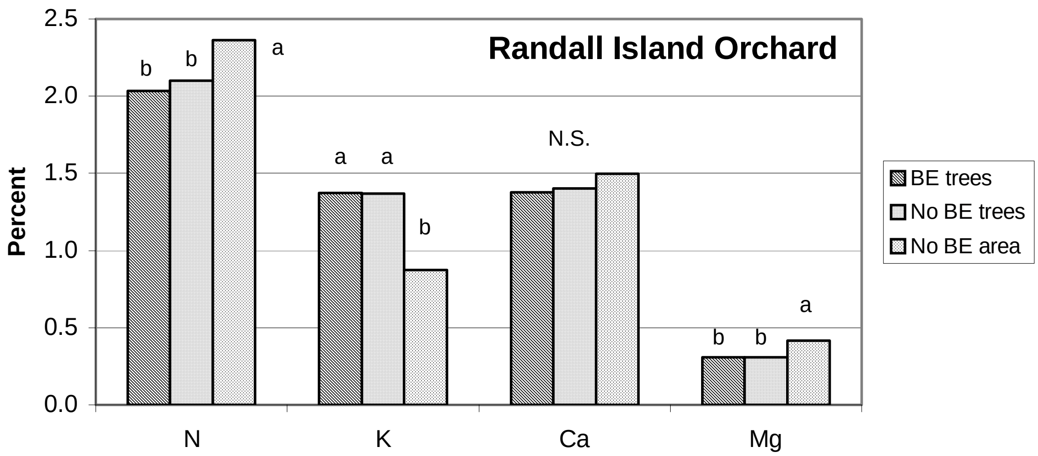


Figure 4. Nutrient content of black end fruit, fruit without black end but from the same black end trees, trees without black end but in an area with a large amount of black end, and trees in an adjacent area that had no black end present, Randall Island orchard (Fisher's LSD, P>0.05).

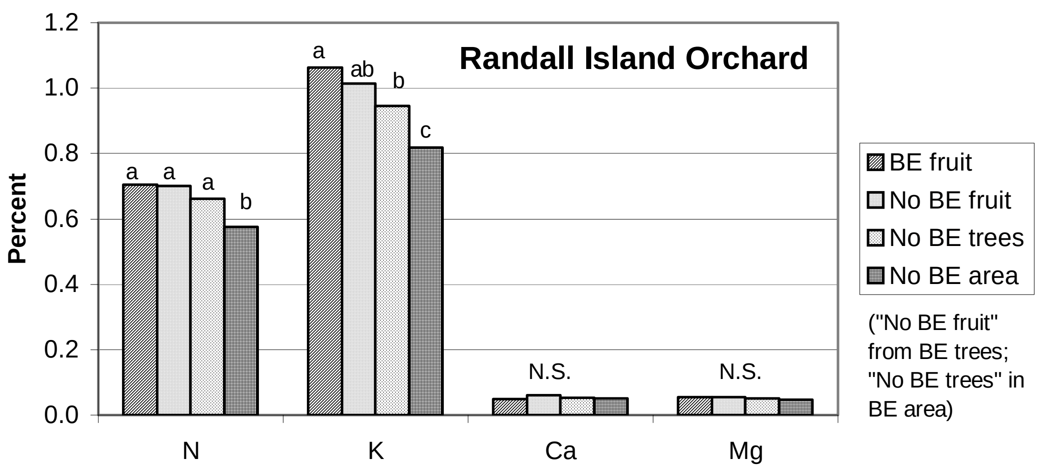


Figure 5. Nutrient content of soil under trees with black end vs. soil from an area with no black end present, Randall Island orchard.

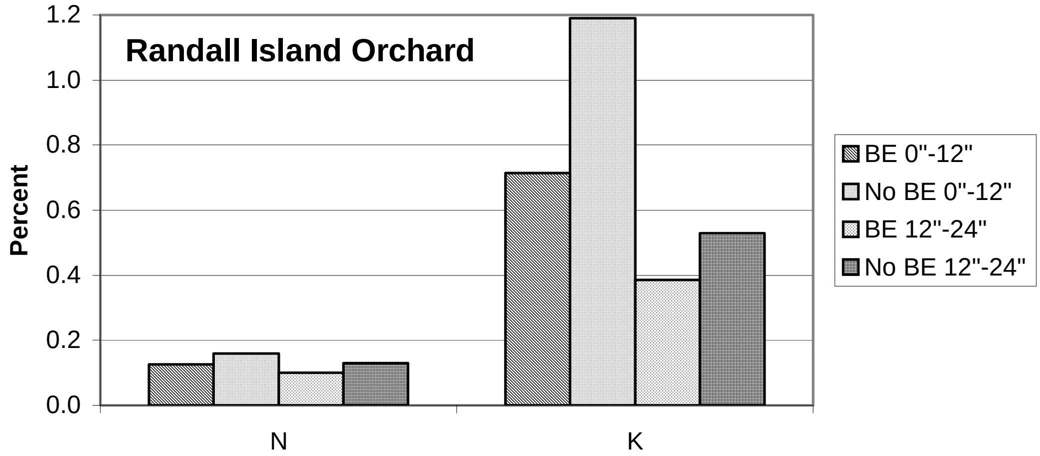


Figure 6. Nutrient content of fruit from trees with black end vs. trees without black end, Twin Cities Rd. orchard (Fisher's LSD, P>0.05).

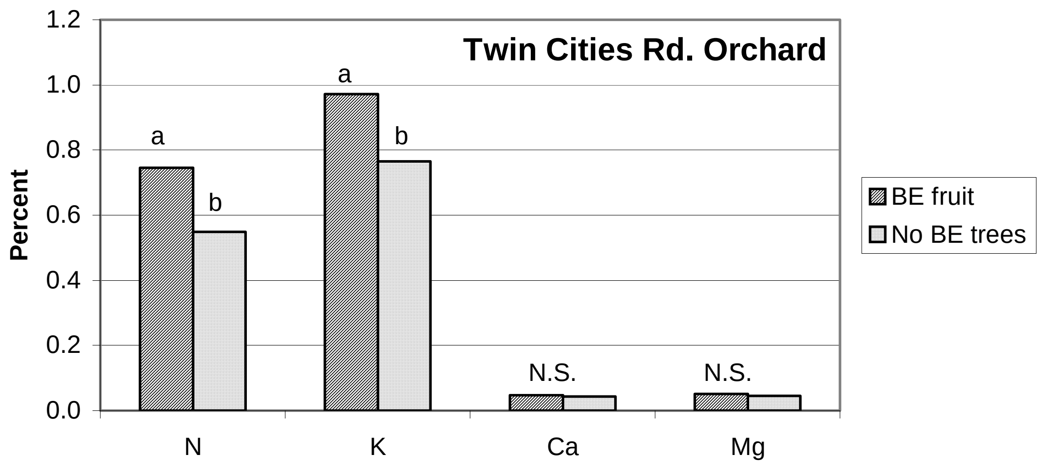
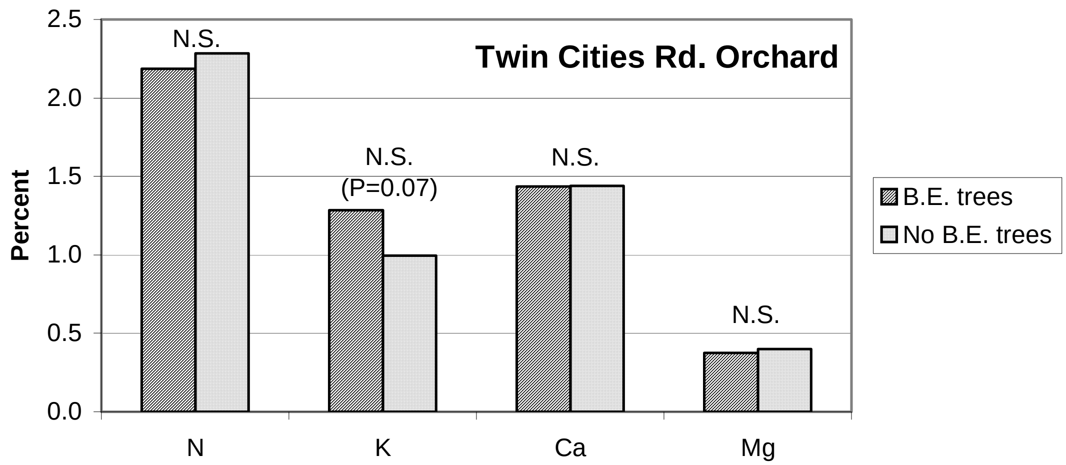


Figure 7. Nutrient content of <u>leaves</u> from trees with black end vs. trees without black end, Twin Cities Rd. orchard (Fisher's LSD, P>0.05).



<u>Discussion</u> (Objective 1)

The black end seen in these orchards was likely mostly a rootstock effect. In the Randall Island orchard, even though the group of trees without black end were in the same row (at one end) as the black end trees (Figure 8), the non-black-end trees were clearly older. The grower states that portions of the block were planted at different times as a result of pear decline, and that the older trees (60+ yrs.) are on Winter Nelis and the younger trees (30-40 yrs., with black end), are on *P. betulaefolia*. Similarly, at the Twin Cities Rd. orchard, the area with the calcium trial (see Figure 10) is on Winter Nelis but the replants (with black end) are on *P. betulaefolia*. In the block adjacent to the calcium trial (Figure 9), black end occurred on a few green Bartlett trees (most likely replants on *P. betulaefolia*), and on all the Rosired trees, which were interplanted (probably on *P. betulaefolia*). The Merritt Island orchard, which had a drainage problem and extensive black end in 2004, is on Winter Nelis but it is not known on what rootstock the single tree with black end was grafted.

Figure 8. Areas of study at the Randall Island orchard, showing the black end study area in the same rows as an area with no black end at all.

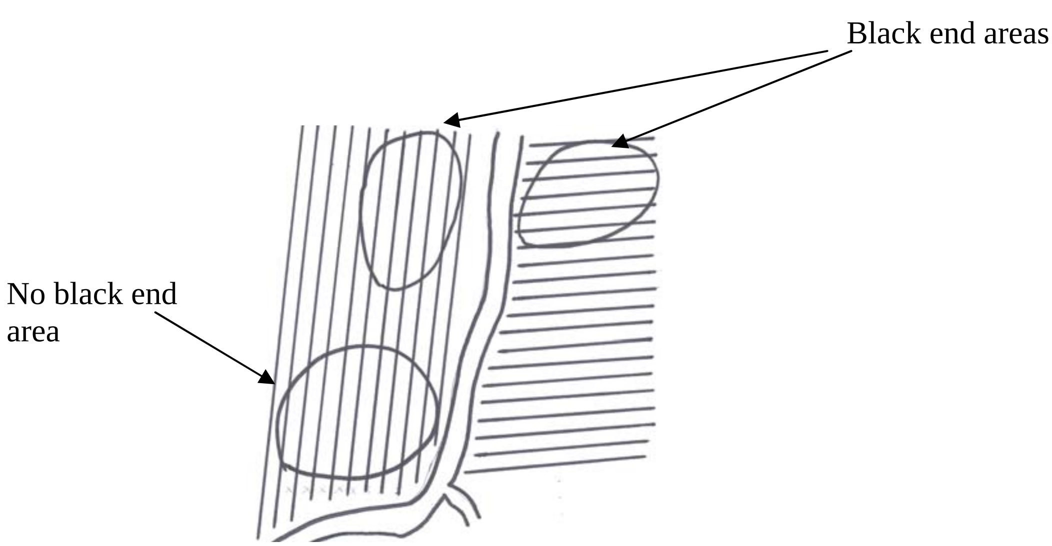


Figure 9. Map of a portion of a block in the Twin Cities Rd. orchard, showing a few black end trees of green Bartlett and all the older interplanted Rosired trees with black end. All black end trees are likely on *P. betulaefolia* rootstock.

	R O W									
Tree	1	2	3	4	5	6	7	8	9	10
1	G	Y	G	G	G	G	R	G	G	G
2	G	R	G	G	G	RY	G	G	R	RY
3	Y	G	G	G	RY	G	G	G	RY	RY
4	G	G	G	G	G	G	G	G	G	G
5	G	G	RY	G	G	G	G	G	G	G
6	Y	Y	G	G	G	G	G	G	G	G
7	G	G	RY	G	G	G	G	G	G	G
8	G	G	RY	Y	G	G	G	G	G	G
9	G	G	G	G	G	G	G	G	G	G
10	G	RR	G	G	G	G	G	G	G	RY
11	G	G	G	G	G	G	G	G	G	G
…	…	…	…	…	…	…	…	…	…	…
32	RR	Y	Y	RY	Y	RY	RY	Y	RY	RY
33	G	G	G	Y	G	G	R R	RY	RY	G
34	Y	RR	RY	R R	R R	R R	R R	RRY	R R	R R
35	G	G	G	Y	Y	G	Y	G	G	G
36	G	Y	G	R R	R R	R R	Y	RRY	R R	R R
37	G	G	RY	Y	RY	G	G	G	Y	Y
38	G	RR	RY	R R	RY	R R	R R	RRY	R R	R R
39	G	G	G	G	G	G	G	G	G	G
40	G	RR	G	R R	R R	R R	R R	RR	R R	R R
41	RY	Y	Y	G	G	G	G	G	G	G
42	RSY	RSY	RY	RY	RY	RY	Y	Y	RY	RY
43	G	G	G	G	G	G	G	Y	G	G
44	RY	RR	G	RY	R R	R R	R R	RY	R R	R R
45	RY	G	G	G	G	G	G	G	G	G
46	G	RR	R R	G	R R	R R	R R	RR	R R	R R
47	G	RY	G	Y	G	G	G	G	RY	G
48	G	RR	RY	R R	R R	R R	R R	RR	R R	R R
49	G	G	G	G	G	G	G	G	G	G
50	G	RR	R R	R R	R R	R R	R R	G	R R	R R
60	G	RR	G	R R	R R	R R	R R	G	R R	R R
61	G	RY	G	G	G	G	G	G	RY	G

N

G = Green Bartlett
R = Red pear
RR = Rosired
RS = Red Sensation
Y = Young tree
RR = Black end (all Rosired)
G = Black end Green Bartlett

The nitrogen and potassium content of fruit from black end trees were consistently greater than those from trees with no black end. Also, the potassium content of leaves from black end trees was consistently greater than that from trees with no black end, but the difference in nitrogen in the leaves was not consistent. Why this difference in potassium content? Raese (1994b) showed that *P. betulaefolia* and *P. ussuriensis* rootstocks have more black end and higher fruit potassium levels than six other rootstocks (Table 2, *P. bet.* and W. Nelis only). Naumann (1959) showed that leaves of trees on *P. betulaefolia* had higher levels of potassium and lower levels of nitrogen and phosphorus. So the nutritional differences in the current study are most likely simply a rootstock effect; *P. betulaefolia* takes up more potassium from the soil than Winter Nelis.

Table 2. Black end rating and nitrogen and potassium content of Anjou fruit in Washington (Raese 1994b).

	Black end (0-5)[1]	% N in fruit flesh (1981)	% K in fruit flesh (1980)	% K in fruit flesh (1981)
P. betulaefolia	2.1 a[2]	0.30 a	0.85 a	1.29 a
Winter Nelis	0.0 b	0.29 a	0.67 b	1.02 b

[1] *Rating of 0 = none; 5 = excessive*
[2] *Means separated by Waller-Duncan, K-ratio, t Test at 5% level.*

Objective 2. To determine if foliar calcium applications reduce black end.

<u>Methods and Materials</u> (Objective 2)

Foliar calcium sprays can be applied to trees in the spring by mixing it with antibiotics and other products. Perhaps 20 percent of the growers in the Sacramento River district spray calcium on Bartlett pears (J. Dahlberg, personal communication). CaliFlow (Phosyn PLC) (4-0-0, with 23.8% Ca), is often applied foliarly by these growers. Another product, ThioCal (Best Sulfur Products) (6.3% Ca and 10% S) is often injected into the irrigation system. In addition to reducing fruit disorders, the application of calcium is reputed to allow the fruit to hang on the tree longer (due to increased firmness) in order to attain larger size.

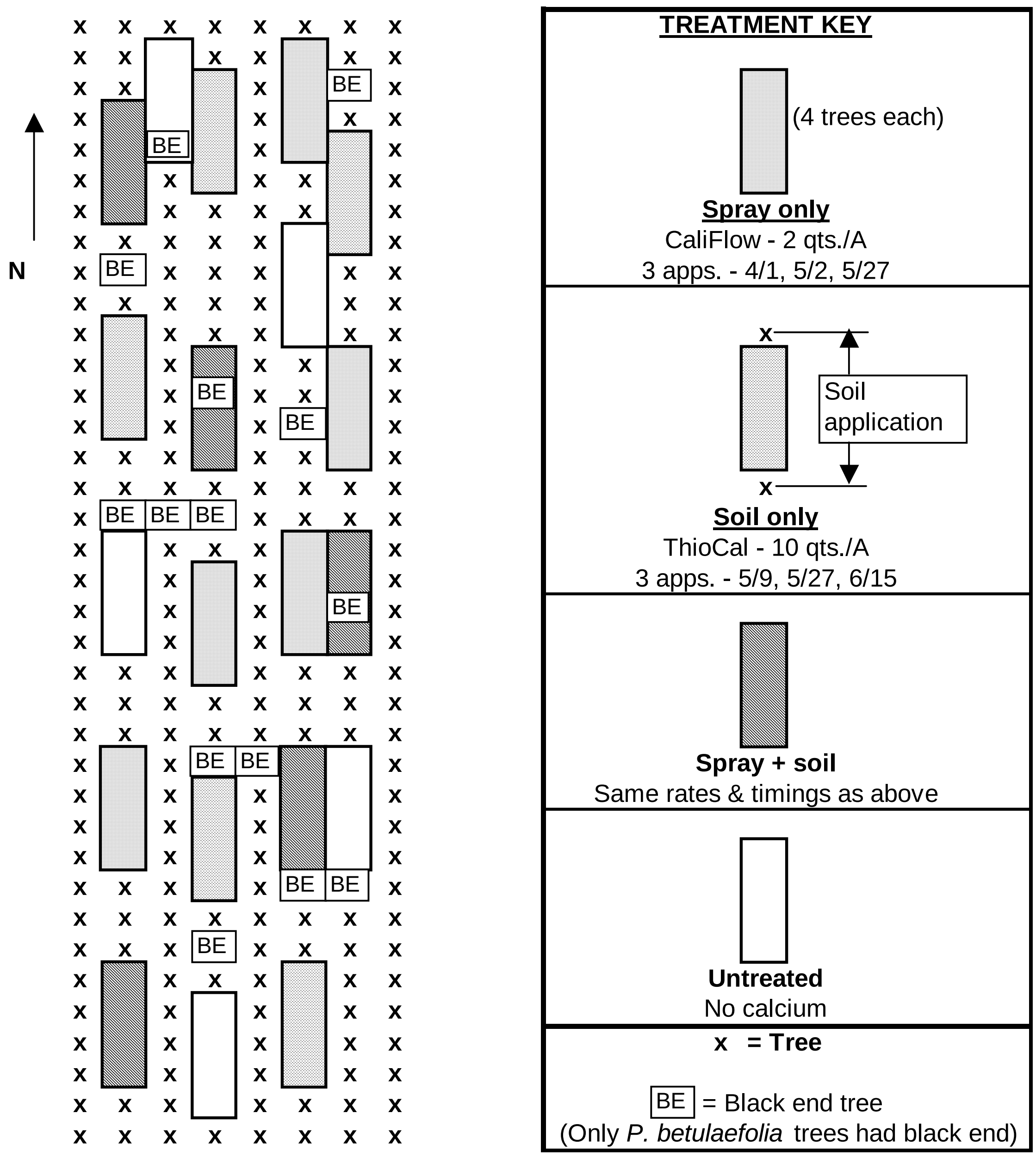
A block that was severely affected in previous years was chosen for this trial. The Twin Cities Rd. orchard (adjacent to the orchard in Fig. 9) consists of Bartlett on Winter Nelis rootstocks (with some exceptions), and the spacing is 10 x 20 ft. The trial was set up in a randomized complete block design, using four treatments and five replicates per treatment (Figure 10). The treatments used were:

1) Three CaliFlow sprays, 2 qts./acre per application. Dates and water rates used:
    a. April 1 – 100 gpa b. May 2 – 200 gpa c. May 27 – 200 gpa
2) Three applications of ThioCal, 10 qts./acre per application (measured quantities poured under each emitter in treatment area).
    a. May 9 b. May 27 c. June 15
3) Three CaliFlow sprays + three applications of ThioCal, same timings and rates as above.
4) Untreated control

No other calcium was applied to the orchard. Four trees were used per treatment replicate. Sprays were applied using a 30-gal. tank with a handgun applicator.

Incidence and severity of black end were determined on each tree just before harvest. The effects of calcium treatments on tissue calcium levels and fruit size were also evaluated. We sampled 25 leaves from non-fruiting spurs in the lower half of each of the four trees (100 leaves per treatment replicate) and consolidated the sample. The leaves were placed in a cooler and then taken to the UC DANR Analytical Lab for nutrient analysis, where we rinsed the leaves in a 1% HCl solution to wash off any remaining unabsorbed calcium adhering to the leaves. We also sampled 10 fruit per tree on each of two trees in each treatment replicate. Fruit size was determined by using an adjustable fruit diameter tool. On July 12, 2005, we measured 25 high and 25 low fruit at random from each of two trees in each treatment replicate (total of 2000 fruit for the entire trial site).

Figure 10. Spray and soil applications of calcium used in this trial, Carmany Ranch. Trees with black end shown (BE).



<u>Results</u> (Objective 2)

The block in which we conducted the calcium trial had 14 trees that, based on rootstock sucker growth, we identified as *P. betulaefolia*; all these trees (and only these trees) had at least some fruit with black end (Figure 10). Only three trees in the calcium-treated plots had *P. betulaefolia* rootstock with black end. One tree in an untreated control plot had 15 fruit with black end, and one tree in each of two spray + soil plots had black end: 1 black end fruit on one tree and 39 black end fruit on the other tree. Therefore, it is not possible to evaluate the effects of calcium treatments on black end.

Although there was slightly more calcium in leaves of trees treated with spray and spray + soil, it was not significantly more due to high variability (Table 3). There were also no significant differences among treatments in calcium content of fruit (Table 3), nor were there differences in nitrogen, potassium, or magnesium (data not shown). Fruit size among treatments was virtually identical (Table 4).

Table 3. Calcium content of leaves and fruit in calcium treatments.

	Leaf (%)	Fruit (%)
Untreated	1.22 a	0.045 a
Spray only	1.30 a	0.050 a
Spray + soil	1.35 a	0.048 a
Soil only	1.25 a	0.041 a

Means with the same letter in each column are not significantly different (Fisher's LSD, $P<0.05$).

Table 4. Mean fruit diameter in calcium treatments, July 12, 2005.

	Fruit size (in.)
Untreated	2.50 a
Spray only	2.50 a
Spray + soil	2.51 a
Soil only	2.50 a

Means with the same letter in each column are not significantly different (Fisher's LSD, $P<0.05$).

<u>Discussion</u> (Objective 2)

In the Pacific Northwest, several Anjou fruit disorders are associated with calcium deficiency, including cork spot, alfalfa greening, stony pit, and black end. For years, calcium chloride ($CaCl_2$) sprays have been applied to reduce these disorders. Foliar $CaCl_2$ applications on Anjou pears are recommended at 1.5 lbs./acre, five times per season (Raese 2000). Calcium-containing chelates and organic complexes have been found to be less effective than calcium chloride. CaliFlow is neither of these – it consists primarily of calcium carbonate.

$CaCl_2$ has about 36 % Ca, and it is generally about 94% pure. Therefore, this standard foliar $CaCl_2$ program applies 2.5 lbs./acre of Ca per year (1.5 lbs./acre x 5 times x 36% x 94%). CaliFlow (4-0-0) contains 23.8% Ca and each gallon contains 3 lbs., 5 oz. (3.3 lbs.) of Ca. We sprayed 2 qts./acre three times, for a total of 6 qts., or 1.5 gal., which contains 5 lbs. Ca/acre (3.3 x 1.5). Therefore, we applied double the standard rate of foliar calcium. This rate barely increased leaf calcium content and did not increase fruit calcium, even with added soil calcium. Nor did these treatments increase fruit size.

Calcium chloride can cause fruit russetting with increasing number of applications, high rates, and when applied at less than 100 gallons per acre (Peryea and Willemsen 2000). The possibility of injury is highest at gallonages where droplets coalesce and pool on the lower part of the fruit. The hazard is reduced by using low rates and dilute sprays (i.e., 1.5 lbs./acre in 100 gal. water), and avoiding spraying it under slow drying conditions or at temperatures above 80 to 85ºF. In our trial, we did not evaluate russetting.

References

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