Yield Increased and Fruit Disorders Decreased with Repeated Annual Calcium Sprays on 'Anjou' Pears

J. T. Raese
S. R. Drake

ABSTRACT. Yield of 'Anjou' pears, *Pyrus communis* L., was increased with repeated annual (9-13 years) calcium chloride ($CaCl_2$) sprays. The incidence of fruit disorders (alfalfa greening and cork spot) was decreased by $CaCl_2$ sprays with or without Regulaid but some minor calcium spray phytotoxicity occurred on fruit and leaves. Fruit calcium concentrations in peel and cortex were increased with calcium chloride sprays; however, these sprays had little or no effect on leaf weight, fruit size, leaf Ca concentrations, tree vigor, shoot growth, fruit firmness, soluble solids, titratable acids, fruit color, fruit rots, or storage scald. This study suggested that long-term calcium chloride sprays of 60.5 g Ca per 100 liters of water or 33 to 44 kg $CaCl_2$ per ha should provide the pear grower with a means of not only controlling fruit disorders but also for increasing 'Anjou' pear yield. *[Article copies available from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworth.com]*

KEYWORDS. Mineral concentration, disorders, vigor

J. T. Raese is Plant Physiologist (Collaborator) and S. R. Drake is Horticulturist, U.S. Department of Agriculture, Agricultural Research Service, Tree Fruit Research Laboratory, 1104 N. Western Avenue, Wenatchee, WA 98801.

The authors acknowledge Agricultural Technicians P. Fletcher, K. Hansen, S. Ivanov, D. C. Staiff and orchardists Bitterman and Flick, Naumes, Inc., and F. Shannon, and financial support from the Winter Pear Control Committee of the Washington, Oregon, California Pear Bureau.

Journal of Tree Fruit Production, Vol. 1(2) 1996

INTRODUCTION

Sufficient calcium (Ca) in fruit of 'Anjou' pears, *Pyrus communis* L., is needed to alleviate certain fruit disorders (Mason and Welsh, 1970; Raese, 1989; Raese et al., 1979; Richardson and Al-ani, 1982; Woodbridge, 1971). Various fruit disorders of 'Anjou' pears can be controlled by different formulations of Ca sprays (Raese, 1988; Raese 1994; Raese and Drake, 1993; Raese and Stahly, 1982; Richardson and Lombard, 1979). Because of possible Ca-spray injury to pear leaves and fruit, Ca sprays were not recommended to pear growers in the Pacific Northwest until the mid-1980s when Raese and Stahly (1982) reported that reducing the calcium chloride ($CaCl_2$) rates recommended for apple trees by one-half reduced spray injury to leaves and fruit of 'Anjou' pears without losing the beneficial effects of the Ca sprays.

The objectives of this study were to evaluate the effects of long-term Ca-spray applications on 'Anjou' pear yield and fruit quality from three different orchards in north-central Washington.

MATERIALS AND METHODS

Three irrigated 'Anjou' pear orchards were selected for the study because the trees had a history of a high incidence of alfalfa greening or cork spot fruit disorders (Raese, 1989; Raese et al., 1979). Trees were in their prime for fruit production and were approximately 14 to 20 years old at the start of the long-term experiments in 1978 or 1979. The Ca treatments were applied to the same set of trees in each orchard for the duration of the experiments.

Cashmere Orchard (1979-91). The orchard was located near Cashmere, Washington and consisted of a block of uniform 20-year-old trees growing on 'Bartlett' seedling rootstocks. The trees were spaced at 7.2 × 5.4 m apart with guard trees separating spray treatment trees and with a grass cover crop growing underneath. The soil was a Burch fine sandy loam with a 3 to 10% slope having a southerly exposure. Prior to the experiment, up to 38% of the culled fruit in this orchard during a single season had been lost due to cork spot (Raese, 1994).

The experimental design was a randomized complete block with 15 single-tree replications. The three treatments were unsprayed control, $CaCl_2$, and $CaCl_2$ + a surfactant. Calcium chloride (34% Ca) was applied at a concentration of 60.5g Ca/100 liters of water (approx. 6,000 liters per ha) with and without a surfactant Regulaid™, (polyoxyethylenepolypropoxypropanol; Dihydroxypropane; alkyl,2-ethoxyethanol) at 62.4 ml/100 liters. Spray applications averaged four times per season during June to August. Sprays were applied with a hand gun until run-off (dilute spray method).

Chelan Butte Orchard (1979-1986). The orchard was located near Chelan, Washington. The 14-year-old trees were spaced at approximately 10.8 × 5.4 m and grown in a Supplee fine sandy loam soil having a 0 to 3% slope with an easterly exposure. In a strip-block design, spray treatment trees were assigned randomly within each row and were separated by guard trees. The treatments consisted of six single-tree replicates of unsprayed controls, $CaCl_2$ (34% Ca), and $CaCl_2$ plus Regulaid. The rates of application were as described for the Cashmere orchard. Four annual spray applications were applied with a hand gun until run-off during June to August. When fruit disorders were first observed in the orchard in 1979, 95% of the trees had fruit with symptoms of alfalfa greening.

Entiat Orchard (1978-1986). The orchard was located about six miles west of Entiat, Washington. Trees were approximately 14 years old in 1978 and grown in a Brief gravelly sandy loam soil with a 3 to 8% slope. Spray treatments consisted of unsprayed controls and three to four annual applications of 404 g Ca/100 liters of water (approx. 950 liters per ha) during June, July and August. In addition, the $CaCl_2$-treated trees also received one or two applications of Nutra-phos 24 (NP-24) at 286 g Ca per 100 liters of water in May and/or September each year. NP-24 was produced by Leffingwell and contained 20% Ca. Applications were made during the early morning hours to avoid high daytime temperatures which might cause spray injury to leaves and fruit. In a strip-block design with a guard row separating treatments, treatments were applied to 20 single-tree replications. Prior to Ca spray treatments in 1978, 20% of the packout was culled due to alfalfa greening and frost damage to fruit.

Analysis. Orchard observations on leaf and fruit injury from Ca sprays were made immediately before harvest. The rating system consisted of 1 = very slight, 3 = borderline acceptable, 5 = very severe spray injury. Also at this time, visual estimates of shoot growth, tree vigor, fruit size, and incidence of fruit disorders (alfalfa greening, black end, cork spot, and stony pit) were determined at harvest time in late August to mid-September each year with a 1 to 5 rating system where 1 = least and 5 = highest vigor, yield, or fruit disorder. Yield (number of boxes per tree) was determined by counting the number of fruit on each tree and dividing by box size such as 100 fruit per box being typical.

Twenty leaves per tree were collected in August from each orchard and weighed, washed, and oven-dried for leaf analysis. A ten-fruit sample from each tree was collected at harvest time and stored for four to six months at $-1.0°C$. The fruit then were washed, weighed, and assessed for overall appearance, fruit color, rots, storage scald, spray injury, and incidence of fruit disorders.

Leaf and fruit concentrations of N, P, K, Ca, Mg, Al, B, Cu, Fe, Mn, Na, and Zn were measured. Total N was determined with a Leco FP 228 N analyzer. The other nutrient concentrations were determined with a Beckman Spectospan Plasma Emission spectrometer. Opposing longitudinal wedges of the fruit were divided into peel and cortex (flesh) on adjacent sides of the blush side of the fruit (Raese and Staiff, 1983). The core and seeds were excluded.

A model EP1 pressure tester (Lake City, Kelowna, B.C. Canada) equipped with a 7.8 mm head was used to determine fruit firmness. Juice extracted from pear slices was titrated to pH 8.2 with 0.1 N NaOH, and values were expressed as percentage of malic acid. Soluble solid content (SSC) was determined with an Abbe-type refractometer calibrated at 20°C.

Analyses of variance were conducted by MSTAT (Michigan State University, E. Lansing, MI, USA), with Ca sprays as the main plots and years of application as sub-plots. Based on significant F values, treatment means were separated by Duncan's multiple range test. No interactions between Ca spray materials and year of application existed, therefore, only the main effect is presented.

RESULTS

In all three orchard locations, yield of 'Anjou' pears was increased with long-term sprays of $CaCl_2$ (Table 1). Fruit size was not affected by $CaCl_2$ or $CaCl_2$ + Regulaid sprays while shoot growth and tree vigor were sometimes reduced by $CaCl_2$ sprays. Spray injury or phytotoxicity occurred on fruit and leaves sprayed with $CaCl_2$. These spray markings should be considered acceptable for marketing of fruit, since ratings were all less than 3. Although it may be difficult to compare orchards, spray injury to fruit and leaves appeared to be slightly less severe with concentrate sprays (Entiat) than with dilute sprays (Cashmere and Chelan Butte). At the Entiat location, the trees were sprayed with concentrate $CaCl_2$ early in the mornings when temperatures were coolest.

Leaf weights were unaffected by treatments (Table 2). Fruit weights were not affected by treatment in the Cashmere and Chelan Butte orchards but were slightly reduced by $CaCl_2$ at the Entiat location. Fruit peel and cortex Ca concentrations were higher than the controls from trees sprayed with $CaCl_2$ or $CaCl_2$ + Regulaid at the Cashmere location (Table 2). Peel Ca concentrations were higher from trees sprayed with $CaCl_2$ at the other

TABLE 1. Effects of calcium chloride sprays on shoot growth, tree vigor, yield, fruit size, and spray injury to fruit and leaves of ‘Anjou’ pears at three locations.

Calcium spray treatments and content[z]	Ca per 100 liters H_2O	Shoot growth (1-5)[x]	Tree vigor (1-5)[x]	Yield (boxes/tree)	Fruit size (#/box)	Spray injury Fruit (1-5)[x]	Spray injury Leaves (1-5)[x]
Cashmere orchard (1979-1991)							
Control	none	4.2 ^{ns}	4.5 a[y]	9.5 b	91 ^{ns}	0.6 b	0.4 b
$CaCl_2$ (34% Ca)	60.5 g	4.0	4.1 b	11.3 a	91	2.4 a	2.2 a
$CaCl_2$ + Regulaid	60.5 g +	4.3	4.6 a	11.9 a	91	1.8 a	1.9a
(Dilute sprays)	62.4 ml						
Chelan Butte (1979-1986)							
Control	none	4.0 ^{ns}	3.8 ^{ns}	7.0 b	106 ^{ns}	0.5 b	0.7 b
$CaCl_2$ (34% Ca)	60.5 g	3.8	3.8	8.1 a	105	2.0 a	2.1 a
$CaCl_2$ + Regulaid	60.5 g +	3.7	3.7	7.2 ab	107	1.3 ab	1.8 a
(Dilute sprays)	62.4 ml						
Entiat orchard (1978-1986)							
Control	none	4.6 a	4.5 a	6.4 b	90 ^{ns}	1.0 b	0.9 b
$CaCl_2$ (34% Ca)	3.8 kg Ca/ha[z]	4.3 b	4.3 b	7.5 a	92	1.1 a	1.8 a
+Nutra Phos-24 (20% Ca)	+ 13.6 kg/ha[z]						
(Concentrate Spray)							

[x]Rating of 1 = very low, 3 = moderate growth or vigor or acceptable spray injury, 5 = luxuriant growth or vigor or excessive spray injury.
[y]Means within column and orchards separated by Duncan’s multiple range test P = 0.05.
[z]$CaCl_2$ applied 3 to 4 times in June to August and Nutra-phos 24 applied in spring and/or fall each year at the Entiat Location at 943 liters/ha.

TABLE 2. Effects of calcium chloride sprays on fresh leaf weight, fruit weight, calcium concentrations in fruit and leaves, alfalfa greening and cork spot disorders (orchard observation) of ‘Anjou’ pears from three locations.

Calcium spray treatments and content	Fresh leaf wts (g)[x]	Lab. fruit wt. (g)	Lab. fruit Ca conc. (dry wt.)		Leaf (dry wt.)	Fruit disorders (orchards)	
			Peel (ppm)	Cortex (ppm)	Ca (%)	Alfalfa greening (1-5)[y]	Cork spot (#/tree)
Cashmere orchard (1979-1991)							
Control	13.3^{ns}	191^{ns}	1575 c[z]	512 c	1.82 b	0.2^{ns}	8.1 a
$CaCl_2$ (34% Ca)	13.6	190	1742 a	579 a	2.00 a	0.2	1.5 b
$CaCl_2$ + Regulaid	13.5	187	1658 b	538 b	1.95 a	0.3	2.9 b
(Dilute Sprays)							
Chelan Butte (1979-1986)							
Control	17.4^{ns}	153^{ns}	2125 b	765^{ns}	1.88^{ns}	3.4 a	1.4 a
$CaCl_2$ (34% Ca)	17.8	159	2239 a	811	1.95	1.2 b	0.2 b
$CaCl_2$ + Regulaid	17.5	155	2180 ab	785	1.83	1.2 b	0.3 b
(Dilute Sprays)							
Entiat orchard (1978-1986)							
Control	NA	204 a	1698 b	509 b	2.06^{ns}	3.1 a	4.8 a
$CaCl_2$ (34% Ca)	NA	191 b	1827 a	558 a	2.14	1.8 b	1.1 b
+NP-24 (20% Ca)							
(Concentrate Spray)							

[x]Total leaf weight of a 24-leaf sample. Refer to Table 1 for Ca rates.
[y]Rating of 1 = slight incidence of alfalfa greening (acceptable); 5 = severe. [z]Means within columns and orchards separated by Duncan’s multiple range test, ($P = 0.05$ except $P = 0.10$ for Chelan Butte and Entiat peel Ca); NA = not available.

two locations. Fruit cortex Ca concentrations also were higher with $CaCl_2$ treatments at the Entiat location. At the Cashmere location, $CaCl_2$ treated trees had higher peel and cortex Ca content than trees sprayed with $CaCl_2$ + Regulaid. Leaf Ca concentrations tended to be higher from trees treated with $CaCl_2$ sprays, but it was only significant at the Cashmere location. Of the nutrient elements analyzed, only Ca appeared to have important concentration gradients.

Incidence of fruit disorders (alfalfa greening and cork spot) were consistently reduced with $CaCl_2$ or $CaCl_2$ + Regulaid sprays (Table 2). Alfalfa greening occurred only slightly at the Cashmere location and only a slight incidence of cork spot was observed at the Chelan Butte location. It is noteworthy that low, moderate, and high concentrations of peel Ca in the control samples from Cashmere, Entiat, and Chelan Butte locations, respectively, were associated with the high, moderate, and low incidences of cork spot (Table 2). The highest concentrations of peel and cortex Ca (from the Chelan Butte $CaCl_2$ or $CaCl_2$ + Regulaid treatments) were associated with the lowest incidence of cork spot. However, this orchard also had the smallest fruit (Tables 1 and 2). Small fruit size is frequently associated with higher concentrations of fruit Ca and a lower incidence of cork spot.

After the fruit were washed, fruit spray mark observations made in the laboratory revealed only minor damage, especially for fruit from trees receiving the concentrate sprays at the Entiat location. Other fruit quality determinations revealed essentially no differences among treatments at any of the three locations (data not shown).

DISCUSSION

Of special interest was the yield increase noted with $CaCl_2$ sprays (Table 1). The occurrence of increased yields at all three locations provides substantial evidence for supporting this important observation, and it suggests the need for further research of Ca sprays on yield of other crops. It should be pointed out that increases in yield did not occur during the first year of observation, and at the Chelan Butte orchard, it did not occur until the third year after $CaCl_2$ sprays were applied. Therefore, yield increases may not be expected from Ca treatment of short duration.

Although several factors may be involved in increasing yield of 'Anjou' pears, we offer the following possible explanations. (1) Because Ca is not considered an easily translocated essential element, a build-up or carry-over effect of Ca concentrations from Ca sprays may be important for improving fruit-set and reducing the incidence of fruit disorders.

(2) Tree reserves of Ca and free Ca concentrations (intracellular Ca) could be important for withstanding winter freezes and spring frosts. Raese (1987) reported increased cold tolerance of apple and pear trees treated with foliar sprays of $CaCl_2$ or Ca $(NO_3)_2$ fertilizers. From 1978 to 1991, Raese (1994) monitored 'Anjou' pear trees for incidence of various fruit disorders, and it was noted that fruit Ca concentrations and production of pears was markedly reduced following record-low temperatures during November and especially in December of 1978, 1983, 1985, and 1990. But Ca sprays at the Cashmere location increased fruit production the following years in 1984, 1986, and 1991 (data not shown). Other researchers (Knight et al., 1991; Minorsky, 1985; Woods et al., 1984) have reported that chill-induced increases in Ca may be a means of protecting cold- sensitive plants against mild chilling stresses. (3) For many years, the possible connection between calcium and pollen tube growth has been recognized, and improvements for detecting small concentrations of various forms of Ca have evolved with time (Miller et al., 1992; Nobiling and Reiss, 1987; Reiss and Herth, 1979). Working with pear pollen, Polito (1983) suggested that there is a maximum concentration of membrane-associated Ca consistent with normal pollen germination and tube growth. Although it is known that excessive concentrations of Ca may disrupt pollen germination and pollen tube growth, we can only speculate that trees receiving several seasons of Ca sprays may be "better equipped" to sustain adequate pollen tube growth than the unsprayed control trees, especially in cold weather. Fruit set of 'Anjou' pear trees is often impaired by prolonged cool periods during blossom development.

In conclusion, our results show that increased fruit Ca concentrations were associated not only with reduced incidences of alfalfa greening and cork spot, but $CaCl_2$ sprays also showed increased long-term yield by an average of 16 to 19%. Orchardists should follow recommendations of local university spray guides or experienced consultants for application techniques to avoid possible undesirable spray injury to leaves and fruit of sensitive pear trees.

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