PRELIMINARY FINAL REPORT
WFTRC Project #AH-01-83 **WSU Project #13C-3619-6748**

Title: Improving Calcium and Zinc Spray Programs for Washington Apple Orchards

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Co-PIs and affiliations:

Calcium
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Dr. Dana Faubion, WSU Cooperative Extension, Yakima, WA

Lenticel breakdown
Dr. Eric Curry, USDA-ARS, Wenatchee

Cooperators: Allan Bros., Naches, WA; Borton & Sons, Tieton, WA

Objective:
The objective of this research was to improve the effectiveness of calcium (Ca) and zinc (Zn) spray programs in Washington orchards therefore influencing plant tissue Ca and Zn status, fruit firmness, and incidences of bitter pit and lenticel breakdown.

Calcium and Zn deficiencies are very common in the Washington tree fruit industry. Low fruit Ca is strongly associated with increased likelihood of bitter pit development and possibly lenticel breakdown in apples. Calcium sprays have been conclusively shown to reduce the likelihood of bitter pit development, while recent research in Brazil concluded that Ca chloride sprays can reduce the incidence of lenticel breakdown in Gala apple. While apple fruit firmness is positively related to fruit Ca concentration, the ability of Ca sprays to increase fruit Ca by an amount that can detectably improve fruit firmness is inconsistent. Low tree Zn status is associated with little leaf, rosetting, leaf chlorosis, blind wood and shoot dieback. These deficiencies are treated with foliar sprays of Zn. Management of Zn nutrition in Washington orchards is particularly problematic because application of the element is regulated by the Washington Department of Agriculture, which seeks to minimize its release into the environment.

Significant findings (based on 2001-02 and some 2003 activities):
NOTE: Research activities are ongoing at the time of report preparation; hence, these findings are subject to change based on impending 2003 results and will be updated for the Research Commission meetings in January 2004.

Boron applied tank-mixed with Zn plus oil at delayed dormant timing is as effective as boron applied at pink timing in apple, pear and sweet cherry [work supported by U.S. Borax and WSU].

Spray application of high rates of Zn sulfate during the dormant period (a traditional recommendation) was the only Zn treatment that substantially improved winter bud Zn status of apple trees, which may account for the longstanding success of this traditional spray. It justifies keeping the current Washington Department of Agriculture exemption allowing higher heavy metal (in this case, Zn) application rates when the heavy metal is required for plant nutritional purposes.

The Zn in the Zn phosphate-based NutraPhos 24 and NutraPhos ZnK is very poorly available. Oxide, basic Zn sulfate, chelated and organically based Zn products contain more-or-less equally phytoavailable Zn, with small differences between products. The main distinguishing characteristic likely will be price per unit phytoavailable Zn.

Calcium chloride sprays substantially reduced bitter pit in HoneyCrisp and Braeburn apple where the incidence of bitter pit was high. Starting sprays in June was more effective than starting sprays in July. Starting sprays in May was no more effective than starting in June.

Calcium sprays had a substantial effect on bitter pit in Fuji apple in 2001 when the background incidence of bitter pit was high but not in 2002 when the background bitter pit incidence was low.

Boom-spray applications of high rates of Ca thiosulfate to soil failed to increase fruit Ca concentration or to reduce bitter pit incidence in apple.

Contrary to a Polish report, applying very high rates of Ca as Ca chloride or MiraCal one week before harvest failed to improve apple fruit firmness. Calcium in Ca chloride is more phytoavailable than Ca in MiraCal, at equivalent total Ca rates.

TechSpray Copper (Nutrient Technologies) at the 2-quart/acre rate applied at first cover substantially improved internal leaf Cu concentrations of Golden Delicious apple trees compared to the previous year (from 4.5 to 14 mg/kg).

Methods, results and discussion (2001-2003):

The complete experimental results for 2003 are not available at the time of report preparation because sample collection, processing, analysis and interpretation are ongoing. Most of data should be available in time for the Research Commission review meeting in January 2004.

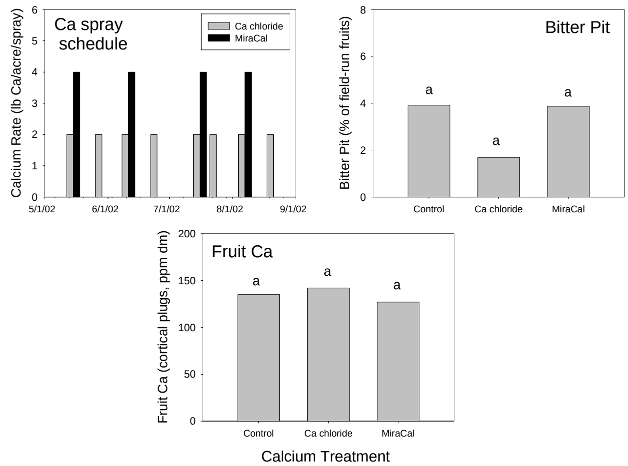
Study 1. Evaluate the effect of Ca and potassium sprays on the incidence of lenticel breakdown on Fuji and Gala apples.

In response to a request by industry personnel, I established collaboration in 2003 with Dr. Eric Curry, USDA-ARS, Wenatchee. Field trials were conducted in which multiple Ca and potassium sprays were applied to Fuji and Gala apples in an attempt to influence the incidence of lenticel breakdown. My program contributed technical field support for the experiments. The results of this study will be provided in the report by Dr. Curry at the Postharvest Review of the Research Commission.

Study 2. Compare the effect on bitter pit of MiraCal sprays applied at low-frequency high-rate with Ca chloride sprays applied at high-frequency low-rate.

MiraCal is believed to be less phytotoxic but is more expensive than foliar-grade Ca chloride. The objective of this experiment is to determine if using fewer applications at higher Ca rates can reduce the net cost of MiraCal sprays. The main cost saving comes from reducing the number of sprays required during the season. Four sprays of MiraCal at 12 lb Ca/acre/spray were compared to eight sprays of Ca chloride at 6 lb/acre/spray on Fuji apples at WSU Smith Tract. Results in 2001 indicated that Ca chloride provided superior bitter pit control over MiraCal. There was no treatment difference in either bitter pit incidence or fruit Ca concentration in 2002, probably due to the very low incidence of bitter pit in that year (Fig. 1). Differential Ca spray treatments were applied in 2004, fruit samples were collected at commercial harvest and are being assessed for mass, bitter pit incidence and fruit Ca content.

Fig. 1. Fuji apple, Smith Tract, Orondo, 2002
8 biweekly sprays of Ca chloride at 2 lb Ca/ac/spray;
4 monthly sprays of MiraCal at 4 lb Ca/acre/spray



Study 3. Determine best start timing for Ca sprays for bitter pit control.
There is a belief that starting Ca spray application during the cell division stage of fruitlet development may enhance bitter pit control. A study was conducted starting in 2002 on Braeburn apple at Allan Bros., Naches, and on HoneyCrisp apple at Borton & Sons, Tieton, evaluating the effect on bitter pit and fruit Ca of six biweekly sprays of Ca chloride at 6 lb/acre/spray starting in May, June or July. The Ca sprays had no effect on fruit mass or firmness and substantially reduced bitter pit incidence (Figs. 2 and 3). The sprays started in May and June were more effective at controlling bitter pit than the July-start spray on the HoneyCrisp, but there were no treatment differences on the Braeburns. Fruit Ca concentration tended to be higher in the later start spray treatments. The experimental treatments were repeated in 2003. Fruit samples were collected at commercial harvest and are being assessed for mass, bitter pit incidence, firmness and fruit Ca content.

Fig. 2. Allan Bros., Naches, 2002
3 weekly soil sprays of ThioCal starting May 8 (40 gal/sprayed acre/spray);
6 sprays of 6 lb $CaCl_2$/acre/spray starting in mid-May, mid-June, or mid-July

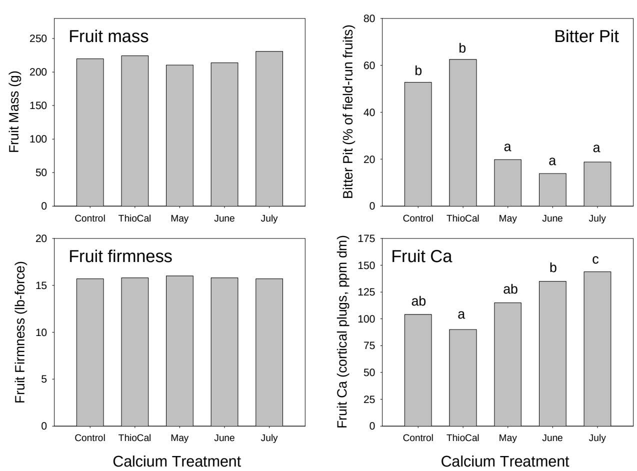
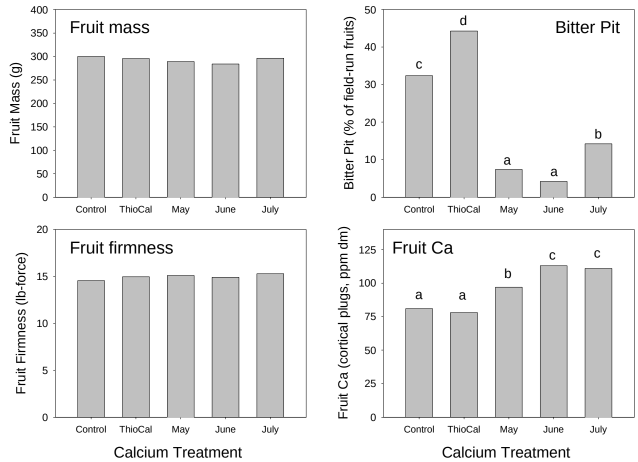


Fig. 3. HoneyCrisp apple, Borton & Sons, Tieton, 2002
3 weekly soil sprays of ThioCal starting May 8 (40 gal/sprayed acre/spray);
6 sprays of 6 lb $CaCl_2$/acre/spray starting in mid-May, mid-June, or mid-July



Study 4. Effectiveness of soil-applied ThioCal (calcium thiosulfate) on bitter pit.
Fuji apple, WSU Smith Tract; Braeburn apple, Allan Bros., Naches; and HoneyCrisp apple, Borton & Sons, Tieton. Soil application of ThioCal at high rates (120 gal/sprayed acre) has been reported to enhance tree Ca status and improve fruit quality. We evaluated three weekly soil-applied sprays of Thiocal at 40 gal/sprayed acre/spray (total 120 gal/sprayed acre) at two locations and a single spray of 120 gal/acre at one location. The soil applications of ThioCal failed to influence fruit Ca concentration or firmness (Figs. 2 and 3). It increased bitter pit incidence in one of the test sites, which may be a statistical anomaly. The experimental treatments were repeated in 2003. Fruit samples were collected at harvest and are undergoing analysis.

Study 5. Effect of immediate preharvest sprays of very high rates of Ca on fruit firmness.
A Polish report in fall 2001 claimed that very high rates of Ca chloride applied one week before harvest consistently enhanced firmness retention by about 20% in Jonagold apples stored in refrigerated air for 120 days. I conducted a study in 2002 examining the effect of Ca chloride or MiraCal application at 20 lb Ca/acre 7 to 9 days before harvest on firmness and Ca content of Gala, Golden Delicious, Braeburn and Fuji apples. The high Ca sprays failed to improve fruit firmness at harvest or after 30 days storage in refrigerated air (Fig. 4). The apples treated with Ca chloride had a readily observable film of moisture on their surfaces, consistent with its high hygroscopicity and ability to pull and retain moisture out of the air. The Ca chloride caused no injury on the fruit. The MiraCal dried as a powdery white coating. It caused no injury on the Braeburn, Golden Delicious and Gala apples but caused lenticel burning on every one of the MiraCal-sprayed Fuji apples. Considerably more Ca was taken up by the fruit treated with Ca chloride than with MiraCal (Fig. 5). It appears that the published benefit of the high Ca treatment on apple firmness may be cultivar-dependent or expressed only when fruit is unusually stressed, such as by long-term refrigerated air storage as was done in the Polish study (120 days). This study was not repeated in 2003 because of failure to find any beneficial effect on fruit firmness.

Fig. 4. Effect of very high Ca spray (20 lb Ca/100 gal) applied one week before harvest on firmness of apples at-harvest or stored 30 days in refrigerated air, 2002. (Cont=control; Mira=MiraCal; Ca=CaCl2; 0=at-harvest, 30=30 days storage)

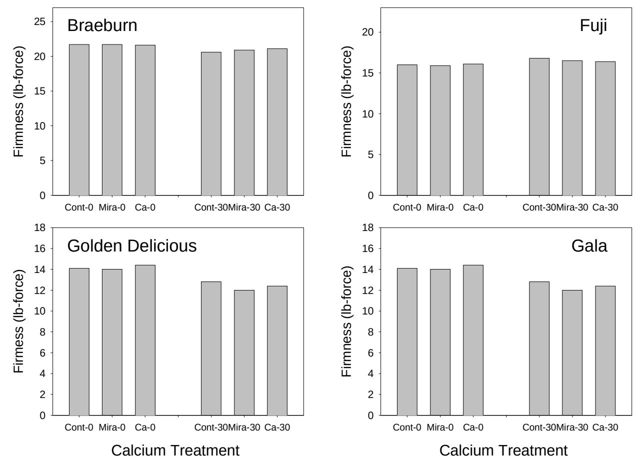
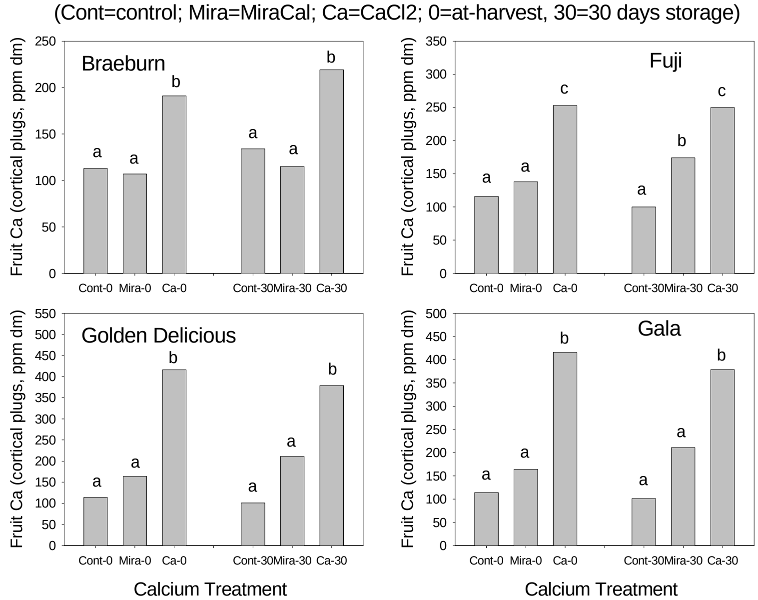


Fig. 5. Effect of very high Ca spray (20 lb Ca/100 gal) applied one week before harvest on fruit calcium of apples at-harvest or stored 30 days in refrigerated air, 2002. (Cont=control; Mira=MiraCal; Ca=CaCl2; 0=at-harvest, 30=30 days storage)



Study 6. Evaluation of 12 Zn spray products for postbloom use.

Fourth year of a field trial examining the effectiveness of multiple postbloom applications of 12 Zn spray products. The Zn products are Biomin Zinc (JH Biotech), CM Liquid 9% Zinc (Custom Ag Formulations), Keylate Zinc (Stoller), Nutra-phos 0-24-0 (Pace International), Nutra-phos Zn-K (Pace International), Nutra-spray Zinc (Pace International), Tech-flo Zeta Zinc 22 (Nutrient Technologies), Zinc Metalosate (Albion Laboratories), Zinc X-tra (Custom Ag Formulations), ZincMax (Plaaskem), Zinc polyamine (Phyto Chem), and reagent-grade Zn nitrate. During the 2000-2002 seasons, the Zn sprays were applied twice postbloom to bearing Golden Delicious apple trees at a rate equivalent to 0.5 or 1.0 lb actual Zn per acre per spray. Zinc nitrate had the greatest effect on leaf Zn concentration but was likely to cause fruit marking. Zinc in the organically-complexed/chelated forms of Zn was intermediate in phytoavailability, and the inorganic compounds contained the least phytoavailable Zn. (Fig. 6). The average January 2003 bud concentrations of the trees receiving Zn sprays were absolutely higher than the control (Fig. 7); however, the differences were not statistically significant. The bud data do suggest that long-term application of Zn at low rates may have a beneficial effect on tree Zn status, particularly in the spring when Zn deficiency is most likely to occur. All of the compounds can provide sufficient Zn to generate leaf Zn concentrations that are considered desirable if applied at high enough rates; however, the costs of the products are widely divergent and need to be considered, as does the desirability of the goal of minimizing Zn release in the environment. No Zn sprays were applied in 2003, but leaf samples were collected in summer 2003 and are being analyzed for mineral element status to determine the residual effects, if any, of the previous three years of sprays. Bud samples will be collected in January 2004.

Fig. 6. Effect of postbloom Zn sprays on Leaf Zn Status

'Golden Delicious'/M.9 Apple, 2000-02
2 Postbloom Sprays of 0.5 (2000) or 1.0 (2001-02) lb Zn/acre/spray

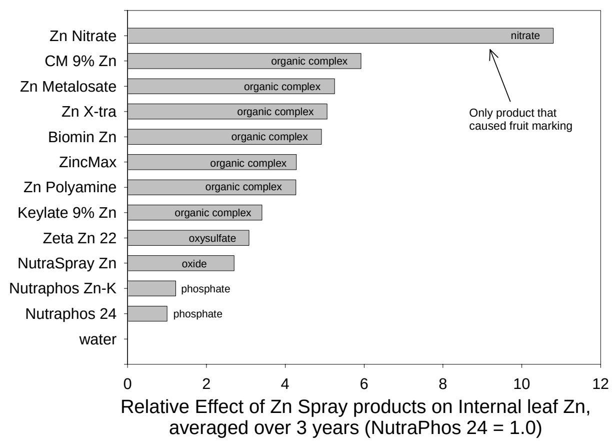
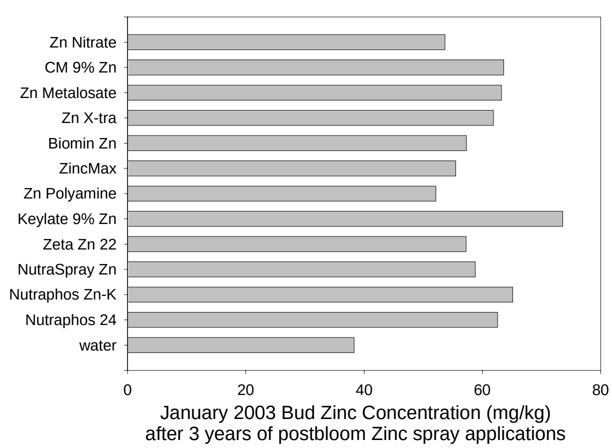


Fig. 7. Effect of postbloom Zn sprays on Bud Zn Status

'Golden Delicious'/M.9 Apple, 2000-02
2 Postbloom Sprays of 0.5 (2000) or 1.0 (2001-02) lb Zn/acre/spray



Study 7. Comparison of Zn application practices.
Third year of a field trial comparing the performance of traditional Zn spray treatments with promising postbloom Zn spray products. Treatments were as follows:

Unsprayed control.

Foliar-grade $ZnSO_4$ (35.5% Zn) applied during the late dormant period (just before any green tissue shows on the buds) at a rate equivalent to 7.329 lb actual Zn per acre [Washington Department of Agriculture maximum rate for Zn contaminant in fertilizer].

Foliar-grade $ZnSO_4$ (35.5% Zn) applied during the late dormant period at a rate equivalent to 3.6645 lb actual Zn per acre.

Foliar-grade ZnO (50% Zn) plus 1% horticultural oil applied at the delayed-dormant stage (green-tip to half-inch green) at a rate equivalent to 2.0 lb actual Zn per acre.

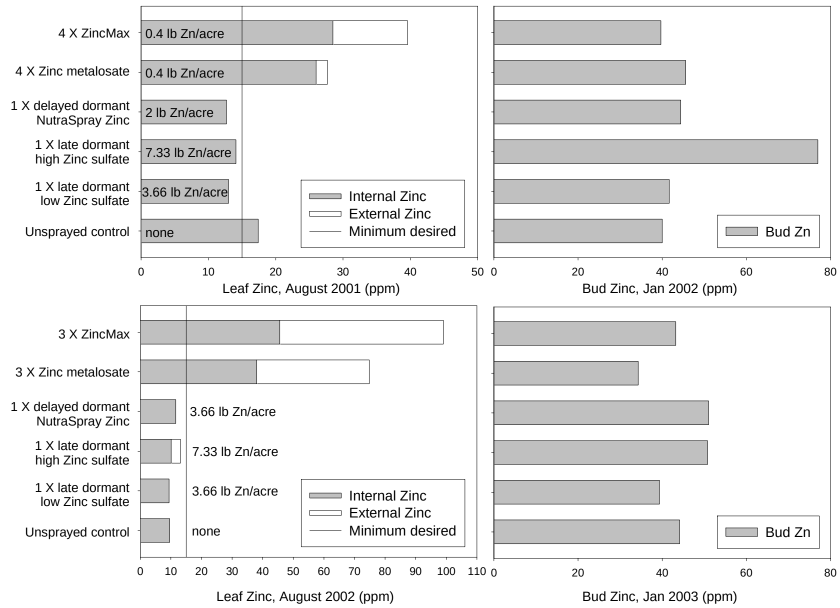
ZincMax applied one week after green-tip, two weeks after petal fall, and four weeks after petal fall at a rate equivalent to 0.10 lb actual Zn per acre per spray.

Albion Metalosate Zinc applied one week after green-tip, two weeks after petal fall, and four weeks after petal fall at a rate equivalent to 0.10 lb actual Zn per acre per spray.

Laboratory studies of Zn solubility in Zn spray solutions, coupled with X-ray diffraction studies, revealed that the current Leffingwell NutraSpray Zinc is formulated entirely with zinc oxide and is not the same product as the classic Leffingwell NutraSpray Zinc 50. The change in formulation accounts for the substantial increase in label rate for the new product.

Leaf samples of 2001-03 were analyzed two ways in order to determine the internal Zn concentration as well as the amount of residues on leaf surfaces (Fig. 8). Internal leaf Zn concentrations were identical in the control, the two zinc sulfates, and NutraSpray Zinc-treated trees. Both ZincMax and Albion Metalosate Zinc substantially increased total and internal leaf Zn, with ZincMax having a greater effect. The substantial increase in January bud Zn observed in 2002 for the high Zn sulfate treatment failed to appear in 2003. Leaf samples collected in summer 2003 are being analyzed for mineral element status. Damage to fruit finish also was assessed. Bud samples will be collected in January 2004.

Fig. 8. Partitioning of total zinc in leaves and buds, 2001-03
Comparison of various zinc spray practices (W18W, Golden Delicious)



Other support of project:
Ca and Zn fertilizer materials were provided by interested fertilizer manufacturers and distributors. Field experimental sites were provided by Borton and Sons, Yakima, and Allan Bros., Yakima, and by WSU. Facilities, analytical instrumentation, PI funding, and the majority of technical support funding were provided by WSU College of Agriculture and Home Economics.

Budget:
Project title: Improving Calcium and Zinc Spray Programs for Washington Apple Orchards
PI: Frank J. Peryea
Project duration: 2001-2003
Project total (3 years): $139,285

Year	**Year 1 (2001)**	**Year 2 (2002)**	**Year 3 (2003)**
Total	48,160	49,905	41,220