Journal American Pomological Society 56(3):136-143 2002

Calcium Spray Materials and Fruit Calcium Concentrations Influence Apple Quality

J. THOMAS RAESE[1] AND S.R. DRAKE[2]

Abstract

Bearing 'Delicious' and 'Golden Delicious' apple trees in three northcentral Washington orchards were treated with up to 12 calcium (Ca) spray materials over five years to determine their effect on fruit quality. In most cases, Ca spray materials, with the notable exception of $CaSO_4$, increased Ca concentrations in the fruit cortex and peel, and reduced the incidence of bitter pit and scald. Fruit firmness and to a lesser extent titratable acids were frequently enhanced with Ca spray materials, especially $CaCl_2$, but soluble solid concentrations were seldom affected. In 'Delicious' apples, fruit appearance and to a lesser degree total red skin area and internal browning control were improved with sprays of $CaCl_2$ or Stopit. None of the Ca spray materials caused unacceptable russet markings on the fruit, but some Ca spray injury occurred on leaves, especially 'Golden Delicious' with the exception of $CaSO_4$ sprays. There was also no apparent affect of Ca sprays on fruit size. Therefore, certain Ca sprays, especially $CaCl_2$-based materials are advantageous for improving fruit quality of 'Delicious' and 'Golden Delicious' apples.

Introduction

With ever increasing global availability of apples and new apple cultivars on the market, competition for the sale of 'Delicious' and 'Golden Delicious' apples has never been greater. Much information is available on calcium (Ca) for the control of bitter pit and corking disorders in apples (4,5) and the importance of Ca on physiological disorders in pears (6,12). However, less information is available concerning the possible role of Ca and Ca sprays for improving apple quality, in addition to reducing the incidence of bitter pit (2,3,9,11).

The objectives of this research were to determine the effectiveness of as many as 12 different Ca spray materials on all aspects of fruit quality of 'Delicious' and 'Golden Delicious' apples over a five-year period in three different northcentral Washington orchards. Mineral analyses of the fruit were also conducted.

Materials and Methods

Mature bearing 'Delicious' and 'Golden Delicious' apple trees on M 7, or seedling rootstocks from orchards near Cashmere, East Wenatchee, and Wenatchee in northcentral Washington were sprayed with 12 different treatments of varying Ca spray products ($CaCl_2$, $CaCl_2$ + Regulaid, Stopit, Mora-Leaf-Ca, Mora-Leaf-Ca + Link Ca, Wuxal, Sorba Ca, Nutri Cal, No. 4-167A, CaB'y, $CaSO_4$, Ca. Metalalosate) over a five-year period. The Ca spray treatments and unsprayed controls were randomly assigned. Treatments were arranged as a randomized block with 16 single-tree replications at the Cashmere location, 6 double-tree replications at the East Wenatchee location, and 12 single-tree replications at the Wenatchee location.

Years 1 and 2. For years 1 and 2, Ca spray treatments and higher than recommended rates are listed in Table 1, for 'Golden Delicious' and in Table 4 for 'Delicious' apples. The earliest spray treatments began on June 11 in the East Wenatchee orchard the first year and on June 6 in Wenatchee the second year and at approximately 3-week intervals and thereafter at all respective locations.

Years 3 and 4. Ca spray treatments and slightly higher than recommended rates are listed in Table 2 for 'Golden Delicious' and in Table 5 for 'Delicious'. The earliest spray treatments began in Wenatchee

[1]Research Plant Physiologist (ret.), USDA,ARS-TFRL. 1104 N. Western Ave., Wenatchee, WA. 98801.
[2]Research Horticulturist, USDA,ARS-TFRL. 1104 N. Western Ave., Wenatchee, WA. 98801.

Table 1. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Golden Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (years 1 and 2).

Calcium Spray Materials (% Ca)	..Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald Area (%)	Firm (lbs)	SSC (%)	TA (% malic)
Control (0% Ca)	0	167a	243c[Z]	629c	14.2a	19.4a	12.2b	14.5a	0.37a
$CaCl_2$ (34% Ca)	1.85	166a	293ab	879a	0.6b	15.4ab	12.7a	14.4a	0.38a
$CaCl_2$ + RA (34% Ca)	1.85	165a	254bc	750b	5.0b	16.8a	12.7a	14.0a	0.39a
Moro-leaf Ca+Link Ca (34% Ca +6% Ca)	2.05	159a	304a	874a	1.4b	14.6ab	12.7a	14.2a	0.39a
Nutri Cal (8% Ca)	0.91	156a	261bc	740b	4.5b	10.9b	12.7a	14.1a	0.38a
No. 4-167A (7.5% Ca)	0.98	164a	278abc	776ab	4.9b	14.9ab	12.6a	14.2a	0.34b
CaB'y (10%Ca; 0.5%B)	1.18	151a	287ab	669bc	1.3b	10.6b	12.5a	14.6a	0.39a

[Z]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test (P≤0.05). RA=Regulaid.

on June 4 and 7 for the third and fourth year, respectively, and thereafter at nearly 3-week internvals at all respective locations. The other two orchard locations were sprayed later, especially the Cashmere orchard which was at a slightly higher elevation.

Year 5. Spray treatments and recommended rates are listed in Table 3 for 'Golden Delicious' and in Table 6 for 'Delicious' trees. The earliest spray treatments were applied in the Wenatchee orchard on June 8 and at approximately 3 week intervals therafter at all respective orchard locations..

All Ca treated trees were sprayed to runoff with a handgun at dilute rates (Ca treatments per 400L of water). Trees in the Cashmere and East Wenatchee orchards received four sprays per season using rates recommended for $CaCl_2$ by the Washington State University Spray Bulletin (15), or manufacturer's suggested rates, while trees in the Wenatchee orchard received three sprays per season at higher (33%) rates of $CaCl_2$ and some others either as early sprays or late sprays in years 1 through 4.

At harvest time in September, a 10-fruit sample was collected from each tree. After 3 to 6 months in regular cold air storage at 0C, the apples were cleaned and weighed and visually rated for overall appearance on the basis of 1=very poor to 8=excellent. Skin color for 'Golden Delicious' was visually rated with the USDA color chart (14) where 1=green and 4=yellow. 'Delicious' apple color was rated on the basis of estimated percent red area on the total apple surface. All apples were also rated for percent of area occupied by scald and or internal browning. The percentage of apples with bitter pit was recorded.

Firmness was determined with the LTP-1 pressure tester (Kelowna, B.C.) equipped with a 1.1 cm probe. Two evaluations per apple were made for each firmness determination. Soluble solids concentration (SSC) and the titratable acid concentration (TA) were determined from an aliquot of expressed juice of a longitudinal slice from each apple. An Abbee-type refractometer with a sucrose scale calibrated at 20C was used to determine SSC. Acids were titrated to pH 8.2 with 0.1N NaOH and expressed as percent malic acid. Elemental analysis of plant tissue was performed using a Beckman Spectra-span V analyzer equipped with a dc argon plasma emission source (Beckman, Brea, CA). Nitrogen was determined with a LECO model FP-228 Nitrogen Determinator (St. Joseph, MI). Analysis of variance was determined using MSTAT C (1988) statistical analysis program. Based on significant F values, treatment means were separated by Duncans's multipe range test.

Results and Discussion

'Golden Delicious' apples

Year 1 and 2. $CaCl_2$-type spray materials including Mora-Leaf-Ca resulted in

Table 2. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Golden Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (years 3 and 4).

Calcium Spray Materials (%Ca)	..Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald (%)	Fruit Appear. (1-8)[Y]	Fruit Color (1-4)[X]	Firm (lbs)	SSC (%)	TA (% malic)
Control (0% Ca)	0	188a	169b[Z]	469c	21.8a	37.3a	5.5bc	3.8a	12.1c	13.8ab	0.297b
$CaCl_2$ (34% Ca)	1.85	185a	240a	724a	2.2b	17.5d	6.2ab	3.1c	12.6ab	13.8ab	0.349a
$CaCl_2$ + RA (34% Ca)	1.85	181a	226a	622b	3.0b	21.5cd	6.1ab	3.6abc	13.0a	14.3a	0.334a
Stopit (12% Ca)	1.51	182a	215a	641ab	4.8b	21.3cd	5.8abc	3.3abc	12.7ab	14.0ab	0.327ab
Moro-leaf Ca + Link Ca (34%Ca+6%Ca)	1.88	185a	248a	729a	3.7b	21.8cd	6.5a	3.1c	12.7ab	14.0ab	0.350a
Wuxal (10.7%Ca + 10%N)	1.37	180a	221a	616b	8.4b	27.7bc	5.9abc	3.1c	12.3bc	13.3bc	0.320ab
$CaSO_4$ (10% Ca + 8% S)	1.71	188a	160b	434c	28.9a	27.5bc	5.2c	3.7ab	12.5ab	14.1ab	0.322ab
Ca Meta (5% Ca + 3% N)	0.61	183a	172b	512c	7.8b	31.7ab	6.1ab	3.5abc	12.6ab	12.8c	0.334a

[Z]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test ($P \leq 0.05$). RA = Regulaid.
[Y]Fruit appearance visual rating (1 = very poor and 8 = excellent).
[X]USDA fruit color chart (1 = green and 4 = yellow).

higher concentrations of Ca in the cortex tissue than in fruit from unsprayed control trees (Table 1). All Ca spray materials except CaB'y produced higher peel Ca concentrations than in fruit from the unsprayed control trees. Although fruit sizes were not significantly different, the fruit sprayed with CaB'y appeared to be smaller and it is surprising that peel Ca concentrations were low considering that cortex Ca was higher than fruit from the controls. Perhaps Ca concentrations in the fruit cortex were relatively higher due to the addition of boron (B) which was believed to assist in more penetration of Ca (personal communication, M. Faust, 1979).

All Ca treatments reduced the incidence of bitter pit (Table1). While all Ca materials tended to reduce the occurence of scald only Nutra-Cal and CaB'y reduced scald significantly. In an earlier report (8) sprays of Ca (6%) and B (1%) or CaCl2 reduced the incidence of senescent scald in 'Bartlett' pears.

Fruit firmness was increased by all Ca sprays (Table 1). Firmness was increased up to 0.5 lbs. while no differences for SSC or TA occurred between treatments, except that TA was lower for fruit from trees sprayed with No. 4-167A.

Years 3 and 4. Fruit size was similar for all Ca treatments (Table 2). Fruit Ca concentrations in the cortex or peel tissues were greater in fruit from trees sprayed with $CaCl_2$, $CaCl_2$ + RA, Stopit, Moro-Leaf-Ca + Link Ca, or Wuxal than in fruit tissues from unsprayed control trees or from $CaSO_4$-treated trees. In many other tree fruit trials (6,7,9,10), Ca sprays containing sulfate had lower concentrations of Ca in the fruit than in unsprayed controls or in other Ca spray treatments; treatments

Table 3. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Golden Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (year 5).

Calcium Spray Materials (% Ca)	..Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald (%)	Firm (lbs)	SSC (%)	TA (% malic)
Control (0% Ca)	0	201a	181b[Z]	554b	7.2a	15.5a	10.7d	12.7ab	0.326c
$CaCl_2$ (34% Ca)	1.29	203a	236a	748a	0.0b	6.0bc	11.6a	13.3a	0.399a
$CaCl_2$ + RA (34% Ca)	1.29	184a	254a	823a	0.0b	7.2bc	10.9cd	12.3b	0.350bc
Moro-leaf Ca+Link Ca (34% Ca +6% Ca)	1.41	200a	231a	745a	0.9b	5.2c	11.5ab	13.2a	0.347bc
Stopit (12% Ca)	1.11	201a	260a	808a	0.5b	9.8bc	11.2abcd	12.7ab	0.384ab
Wuxal (10.7% Ca + 10% N)	0.97	187a	247a	789a	0.1b	7.8bc	11.0bcd	12.7ab	0.388abc
Moro-leaf-Ca (34%Ca)	1.13	192a	240a	778a	0.2b	5.7bc	11.3abc	12.6ab	0.343bc
Sorba Ca (8%Ca + 6%N)	0.86	198a	230a	730a	0.6b	11.2ab	10.9cd	12.6ab	0.366bc

[Z]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test ($P \leq 0.05$). RA=Regulaid.

of sulfate-containing sprays resulted in more fruit disorders such as bitter pit or cork spot.

The incidence of bitter pit was also lower in fruit from trees sprayed with Ca than in the control or $CaSO_4$-treated trees (Table 2). The incidence of scald was lower in fruit from trees sprayed with $CaCl_2$ and $CaCl_2$- based materials (Stopit or Moro-Leaf-Ca) than in the Wuxal, $CaSO_4$, Ca-Metalosate treated trees or the unsprayed control trees. Fruit from trees sprayed with Moro-Leaf-Ca + Link Ca received the highest rating for appearance while the greenest color was observed for the fruit treated with $CaCl_2$, Moro-Leaf-Ca + Link Ca, or Wuxal. The latter Ca material contains N.

Fruit firmness was increased for all Ca spray treatments except Wuxal (Table 2). Highest SSC occurred in fruit from trees sprayed with $CaCl_2$ + RA and lowest SSC occured in the Ca-Metalosate treatment. Titratable acidity was higher in fruit from trees sprayed with $CaCl_2$, $CaCl_2$ + RA, Moro-Leaf-Ca + Link Ca, or Ca-Metalosate than in control fruit. Economically, significance in fruit quality of one treatment over another includes at least 0.5 lbs of firmness, 0.5% SSC and 0.05 or even 0.02% for TA (Personal Communication, K.L. Olsen, 1996).

Year 5. Fruit sizes were similar for all treatments (Table 3). Fruit Ca concentrations were higher than the controls in fruit from trees sprayed with each of the various Ca-spray treatments. Incidences of bitter pit and scald were reduced with all Ca-spray materals. Highest firmness, SSC and TA occurred in fruit from trees sprayed with $CaCl_2$ while lowest firmness and TA occurred in the unsprayed controls.

'Delicious' apples

Years 1 and 2. Fruit size was similar among the different Ca treatments (Table 4). Fruit Ca concentrations in cortex and peel were higher in fruit from trees sprayed with $CaCl_2$; however, the incidence of bitter pit was reduced in fruit from all the Ca-sprayed trees. Scald was lower than the controls on fruit from trees sprayed with Stopit, CaB'y or Nutri-Cal. As previously noted with 'Golden Delicious' (Table 1), the incidence of scald was lowest with the the CaB'y treatment containing B. Although not significant, the lowest incidence of internal browning occurred in fruit sprayed with $CaCl_2$.

In general, fruit appearance was improved for 'Delicious' apples sprayed with the various Ca materials (Table 4). In addition, red color development was improved on fruit from trees sprayed with $CaCl_2$ or Stopit versus the control. Fruit firmness was increased in fruit sprayed with $CaCl_2$ or Nurti-Cal. No significant difference occurred among treatments for TA, but most Ca treatments increased SSC in fruit. It is

Table 4. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (years 1 and 2).

Calcium Spray Materials (%Ca)	Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald (%)	I.B. (%)	Fruit Appear.[Z]	Red (%)	Firm (lbs)	SSC (%)	TA (% malic)
Control (0% Ca)	0	190a[Y]	302b	985b	22.0a	46.5a	19.8a	3.9b	56.1c	13.3c	13.8b	0.278a
$CaCl_2$ (34% Ca)	1.85	187a	340a	1352a	4.5b	41.2ab	11.1a	4.7a	65.5ab	14.3a	14.0ab	0.291a
Stopit (12% Ca)	1.47	195a	300b	950b	6.3b	35.9b	25.2a	4.8a	67.6a	13.4c	14.3a	0.285a
Wuxal (10.7% Ca + 10% N)	1.67	191a	301b	1013b	7.8b	42.5ab	21.1a	4.5ab	60.0bc	13.7bc	14.2a	0.287a
CaB'y (10% Ca + 0.5%B)	1.37	195a	307b	1020b	7.6b	35.2b	19.9a	4.7a	60.5bc	13.7bc	14.2a	0.299a
Nutri Cal (8% Ca)	0.91	1961a	307b	1009b	10.1b	37.0b	20.2a	4.5ab	59.6bc	13.9b	14.3a	0.277a

[Z]Fruit appearance on visual rating (1 = very poor; 8 = excellent). I.B. = Internal Browning.
[Y]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test (P≤0.05).

Table 5. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (years 3 and 4).

Calcium Spray Materials (%Ca)	Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald (%)	I.B. (%)	Fruit Appear.[Z]	Red (%)	Firm (lbs)	SSC (%)	TA (% malic)
Control (0% Ca)	0	209a[Y]	227cd	741c	21.5a	30.6a	13.3a	4.7c	67.8a	13.1b	13.6a	0.196b
$CaCl_2$ (34% Ca)	1.85	205a	275a	925a	2.7b	20.0b	6.8a	6.4a	71.0a	13.9a	13.5a	0.214a
Stopit (12% Ca)	1.51	211a	250bc	837b	4.5b	26.3ab	9.3b	5.7b	68.3a	13.6a	13.5a	0.218a
Moro-leaf-Ca + Link Ca (34%Ca + 6%Ca)	1.88	207a	257ab	839b	3.6b	25.3ab	8.0b	5.8b	64.6a	13.2b	13.6a	0.222a
Wuxal (10.7% Ca + 10%N	1.37	208a	239bc	778c	5.4b	25.4ab	8.3b	5.5b	64.8a	13.6a	13.8a	0.217a
$CaSO_4$ (10%Ca + 8%S)	1.71	210a	222d	746c	18.0a	27.8a	8.4b	5.4b	69.5a	13.6a	13.6a	0.213a

[Z]Fruit appearance on visual rating (1 = very poor; 8 = excellent). I.B. = Internal Browning.
[Y]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test (P≤0.05).

Table 6. Effect of calcium spray materials on fruit calcium concentrations and quality of 'Delicious' apples from orchards near Cashmere, East Wenatchee and Wenatchee, WA (year 5).

Calcium Spray Materials (%Ca)	Ca Rate/ yr (Kg)	Fruit Wt. (g)	Fruit Ca (ppm) Cortex	Fruit Ca (ppm) Peel	Bitter Pit (%)	Scald (%)	I.B. (%)	Fruit Appear.[Z]	Red (%)	Firm (lbs)	SSC (%)	TA (% malic)
Control (% Ca)	0	200a[Z]	247b	864b	14.5a	38.5a	26.1a	5.7d	79.3b	13.4b	13.2a	0.169a
$CaCl_2$ (34% Ca)	1.49	196a	284a	1013a	2.0b	23.6b	21.3a	7.0a	82.7a	14.2a	13.3a	0.179a
Stopit (12% Ca)	1.11	198a	262ab	934ab	3.3b	31.0ab	26.8a	6.5b	86.5a	13.6b	13.3a	0.188a
Moro-leaf-Ca + Link Ca (34%Ca + 6%Ca)	1.41	198a	274a	989a	3.3b	31.4ab	24.4a	6.4bc	81.5ab	13.5b	13.2a	0.184a
Wuxal (10.7% Ca + 10%N	1.13	182a	274a	957a	2.9b	30.6ab	23.8a	6.4bc	79.7b	13.6b	13.1a	0.178a
SorbaCa (10%Ca + 8%S)	0.86	199a	265ab	937ab	6.6b	37.9a	24.6a	6.1cd	79.4b	13.4b	13.2a	0.178a

[Z]Fruit appearance on visual rating (1 = very poor; 8 = excellent). I.B. = Internal Browning.
[Y]Means in a column not followed by a common letter are significantly different by Duncan's multiple range test (P≤0.05).

noteworthy that fruit firmness and fruit Ca concentrations were highest in fruit from the $CaCl_2$-sprayed trees (Table 4).

Years 3 and 4. Fruit weights were similar for all Ca treatments (Table 5). Fruit Ca concentrations in cortex tissue were increased in fruit from trees sprayed with $CaCl_2$ or Moro-Leaf-Ca + Link Ca, while fruit Ca in the peel was highest in $CaCl_2$-sprayed trees followed by Stopit and Moro-leaf-Ca+Link Ca treatments. As was the case for 'Golden Delicious' (Table 2), the incidence of bitter pit was highest in fruit from trees sprayed with $CaSO_4$ or the unsprayed control trees (Table 5). Lowest incidences of bitter pit and scald occurred in fruit from trees sprayed with $CaCl_2$ though not statistically different than some others. A lower incidence of internal browning occurred in all Ca-sprayed fruit.

It is particularly noteworthy when each time $CaSO_4$ sprays or other Ca spray materials containing sulfur were used that fruit Ca concentrations were lower and/or that fruit disorders were higher than with the other Ca spray materials (Tables 2 and 5). This observation was also reported for 'd'Anjou' pears (6,11). In the United Kingdom, certain fungicides containing sulfur have been associated with bitter pit of apples and other fruit disorders (13). Bangerth (1) reported that blossom-end rot of tomatoes was increased with $ZnSO_4$ minus Ca sprays resulting in fruits with the lowest Ca content relative to control and other treatments.

Fruit appearance was improved with all Ca spray materials (Table 5). However, red coloration of fruit was not improved with the different Ca sprays. But $CaCl_2$-sprayed fruit tended to have the highest red color rating. It should be noted that fruit Ca concentrations in the cortex and peel were lower for years 3 and 4 (Table 5) relative to years 1 and 2 (Table 4) or year 5 (Table 6).

Fruit firmness was increased in fruit from trees sprayed with $CaCl_2$, Stopit, Wuxal or $CaSO_4$ (Table 5). There were no differences among treatments for SSC val-

ues. However, TA was higher in fruit from trees sprayed with each of the Ca materials than in the control fruit.

Year 5. Although fruit tended to be small for the Wuxal treatment, no statistical differences in fruit size occurred among the Ca treatments (Table 6). Fruit Ca concentrations in the cortex and peel tissues were increased in fruit from trees sprayed with $CaCl_2$, Moro-Leaf-Ca + Link Ca or Wuxal. All Ca treatments reduced the incidence of bitter pit, while only $CaCl_2$ sprayed fruit had a lower incidence of scald. Internal browning was not affected by Ca treatments in year 5.

Fruit appearance was improved by $CaCl_2$, Stopit, Moro-Leaf-Ca + Link Ca or Wuxal treatments (Table 6). It appears that Ca sprays containing N may not enhance yellow color development in 'Golden Delicious' (Table 2) or red color in 'Delicious' (Table 4,5,6). Red coloration was improved over the control on fruit from trees receiving Stopit sprays. Fruit firmness was increased in fruit from trees sprayed with $CaCl_2$ while no differences among Ca treatments occurred for SSC or TA values.

Fruit Ca concentration was related to various quality attributes such as fruit firmness, TA and fruit disorders (data not shown). Fruit Ca concentrations in peel and cortex tissue were positively correlated with fruit firmness in 'Delicious' apples, TA in 'Delicious' and 'Golden Delicious' and negatively correlated to bitter pit in both cultivars.

Conclusions

Various Ca sprays, especially $CaCl_2$ and $CaCl_2$- based materials, not only reduced the incidence of bitter pit in apples but frequently reduced certain other storage disorders and improved fruit appearance. Fruit quality in the form of fruit firmness and red coloration of peel in 'Delicious' were frequently enhanced with the $CaCl_2$ sprays and it also occasionally increased TA, but SSC was rarely affected by Ca sprays. While the majority of the Ca products improved fruit quality, some of the $CaCl_2$ products had higher rates of Ca per year and it resulted in higher concentrations of fruit Ca and better control of bitter pit. Yet, the $CaSO_4$ treatment had a moderately high rate of Ca per year, but it was associated with the lowest concentration of fruit Ca and the poorest control of bitter pit. No undesirable fruit markings from the different Ca spray materials occurred. However, with the exception of $CaSO_4$, slight injury on 'Golden Delicious' leaves was observed with all Ca sprays, but only at high rates. Trees receiving $CaSO_4$ sprays appeared to be the healthiest with the highest vigor. Therefore, certain Ca sprays, especially $CaCl_2$- based materials, should be considered advantageous for improving fruit quality of apples.

Acknowledgments

The authors acknowledge the finanical assistance of the Washington State Tree Fruit Research Commission for grant funds partially supporting this study. Brand names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard product and the use of names by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

Literature Cited

1. Bangerth, F. 1973. Investigations upon Ca related physiological disorders. Phytopath.Z. 77:20-37.
2. Fallahi, E., T.L. Righetti and J.T. Raese. 1988. Ranking tissue mineral analyses to identify mineral limitations on quality in fruit. J. Amer. Soc. Hort. Sci. 113:382-389.
3. Fallahi, E. and B.R. Simons. 1996. Interrelations among leaf and fruit mineral nutrients and fruit quality in 'Delicious' apples. Jour. Tree Fruit Prod. 1:15-25.
4. Faust, M. and C.B. Shear. 1968. Corking disorders of apples: A physiological and biochemical review. Bot. Rev. 34:441-469.
5. Ferguson, I.B. and C.B. Watkins. 1989. Bitter pit in apple fruit. Hort. Rev. 11:289-355.
6. Raese, J.T. 1989. Physiological disorders and maladies of pear fruit. Hort Rev. 11:357-411.
7. Raese, J.T. 1992. Performance of 'Anjou' pear trees sprayed with calcium or summer pruned. Acta Hort. 322:315-324.
8. Raese, J.T. 1994. Effect of calcium sprays on control of black end, fruit quality, yield and mineral composition of 'Bartlett' pears. Acta Hort. 367:314-322.

9. Raese, J.T. 2000. Calcium can improve apple color and firmness. Good Fruit Grower. 51:32-35.
10. Raese, J.T., S.R. Drake and R.G. Roberts. 1989. Preharvest calcium treatments reduce storage disorders and improve fruit quality of apples and pears. International CA Res. Conf. Proc. 5:53-61.
11. Raese, J.T. and S.R. Drake. 1993. Effects of preharvest calcium sprays on apple and pear quality. J. Plant Ntr. 16:1807-1819.
12. Raese, J.T., S.R. Drake and D.C. Staiff. 1995. Influences of different calcium materials and spray timing on mineral composition, yield, fruit quality, and control of fruit disorders of 'Anjou' pears. J. Plant. Ntr. 18:823-838.
13. Sharples, R.O. and A.H.M. Kirby. 1971. The relationship between different spray combinations of certain fungicides with calcium nitrate and the incidence of bitter pit and fungal desease of apples. J. Hort. Sci. 46:333-346.
14. U.S. Dept of Agriculture, Bureau of Plant Industry. 1929. Standard ground color chart for Apples and Pears in Western States. Washington, D.C.
15. Washington State University. 1991. Crop protection guide for tree fruits in Washington. College of Agriculture and Home Economics, EBO 419. pp. 1-96.