SOME NUTRITIONAL ASPECTS OF PHYSIOLOGICAL DISORDERS OF APPLE FRUIT

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ABSTRACT

SOME NUTRITIONAL ASPECTS OF PHYSIOLOGICAL DISORDERS OF APPLE FRUIT

By

Michael W. Kilby

A study concerning the effect of nutrient sprays on the chemical composition and disorder incidence of selected apple cultivars was conducted in 1969 and 1970.

In 1969 experiments were designed to evaluate the effect of Ca sprays on fruit and leaf composition and physiological disorders of the apple cultivars 'Northern Spy', 'Jonathan' and 'Delicious'. A series of four foliar applications of $Ca(NO_3)_2$ at a concentration of .60% during May and June did not significantly alter Ca content of the fruit or leaves nor did they affect physiological disorders of any cultivar. Two applications of $CaCl_2$ applied during August at a concentration of .60 and .84% with the addition of the chelating agent, Rayplex, significantly reduced the incidence and severity of bitter pit in 'Northern Spy' apple fruit. Leaf scorch was prevalent one week after application. There was a significant positive correlation between bitter pit incidence and fruit size as measured by weight. The results indicated that the Ca content of the

peel appeared to be the dominant factor in reduction of pit formation.

The microprobe was used to examine various tissues of 'Northern Spy' apple fruit with and without bitter pit symptoms. Results showed that necrotic-free tissue from apples exhibiting bitter pit symptoms was low in Ca and Mn and high in K and Mg relative to the content of the tissue from bitter pit free apples. In apples showing bitter pit symptoms, necrotic tissue was higher in K, Ca and Mg than adjacent tissue which appeared to be normal.

In 1970 experiments were designed to determine the effect of foliar applications of $Ca(NO_3)_2$, $MgSO_4$, K_2SO_4, Succinic Acid 2,2-Dimethyl Hydrazide and Triodobenzoic Acid on the nutrition and disorder incidence of 'Jonathan' apple trees and fruit. Three sprays of .60% $Ca(NO_3)_2$ applied at 2 week intervals beginning June 16 significantly reduced internal breakdown (IB) incidence of fruit during storage regardless of type of storage (CA or cold). K_2SO_4 sprays increased fruit K and were the only treatments influencing fruit composition values. However, some spray injury to leaves was prevalent. Addition of the adjuvant, Regulaid, to each of the nutrient spray treatments resulted in a small increase in leaf absorption of the respective element.

Internal breakdown incidence was accentuated when harvest was delayed one week beyond the optimum harvest date. $Ca(NO_3)_2$ plus Regulaid reduced IB even when harvest

was delayed. SADH and TIBA had no effect on IB when fruit were examined after 3 months of cold storage. SADH resulted in a firmer fruit at each harvest date. SADH resulted in a reduction of IB at the later harvest after fruit were kept in CA storage.

Simple linear correlations revealed that IB was negatively correlated with Ca and positively correlated with titratable acidity, fruit K/Ca, Mg/Ca and (K + Mg)/Ca ratios. There was a negative relationship between Ca and titratable acidity. Multiple correlations showed that Ca and titratable acidity was strongly related to IB at optimum harvest and water core was an important factor when harvest was delayed.

SOME NUTRITIONAL ASPECTS OF PHYSIOLOGICAL

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By

Michael W. Kilby

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INTRODUCTION

Annual production of apples in Michigan is approximately 17 million bushels. Michigan ranks third in total U.S. production. The leading cultivar in terms of production is 'Jonathan' which accounts for about 4 million bushels annually. Michigan produces about 40 percent of the nation's 'Jonathan' crop. 'Northern Spy' is the leading processing cultivar in the state.

Growers usually suffer economic losses brought about by low prices, inadequate storage facilities, poor grower management and packing. Losses involved in packing include those caused by physiological disorders which affect primarily 'Jonathan', 'Delicious' and 'Northern Spy' fruit in Michigan. Two disorders which have been of economic importance are bitter pit and internal breakdown. Internal breakdown is more serious with 'Jonathan'. Internal breakdown is a storage disorder and affects the cortical regions of the fruit.

Bitter pit is more severe on 'Delicious' and 'Northern Spy'. Fruit affected with bitter pit show dark pits on the surface of the fruit or just beneath the peel or throughout the flesh. Bitter pit may develop on the tree

or during storage. Symptoms for both of these disorders usually occur at the calyx end of the fruit and in severe cases may affect the entire fruit.

Cultural practices which have been implicated as possible causes are over-fertilization with nitrogen, severe pruning, and severe thinning.

In recent years studies involving the chemical analysis of fruit have revealed that a possible cause for these disorders is manifested in the nutrient content of the fruit specifically related to calcium shortage. However, a cause-effect relationship for this phenomenon has not been established.

Since the cause of internal breakdown and bitter pit have been designated as possible nutrient abnormalities, experiments were conducted to determine the effect of foliar sprays on the nutrient composition and disorder development of the fruit.

EFFECT OF CALCIUM SPRAYS ON MINERAL COMPOSITION AND BITTER PIT OF SELECTED APPLE CULTIVARS

Abstract: In 1969 experiments were designed to evaluate the effect of Ca sprays on fruit and leaf composition and physiological disorders of the apple cultivars 'Northern Spy', 'Jonathan' and 'Delicious'. A series of four foliar applications of $Ca(NO_3)_2$ at a concentration of .60% during May and June did not significantly alter Ca content of the fruit or leaves nor did they affect physiological disorders of any cultivar. Two applications of $CaCl_2$ applied during August at a concentration of .60 and .84% with the addition of the chelating agent, Rayplex, significantly reduced the incidence and severity of bitter pit in 'Northern Spy' apple fruit. Leaf scorch was prevalent one week after application. There was a significant positive correlation between bitter pit incidence and fruit size as measured by weight. The results indicated that the Ca content of the peel appeared to be the dominant factor in reduction of pit formation.

The microprobe was used to examine various tissues of 'Northern Spy' apple fruit with and without bitter pit symptoms. Results showed that necrotic free tissue from apples exhibiting bitter pit symptoms was low in Ca and Mn

and high in K and Mg relative to the content of tissue from bitter pit free apples. In apples showing bitter pit symptoms, necrotic tissue was higher in K, Ca and Mg than adjacent tissue which appeared to be normal.

EFFECT OF CALCIUM SPRAYS ON MINERAL COMPOSITION AND BITTER PIT OF SELECTED APPLE CULTIVARS

By

Michael W. Kilby

Introduction

Physiological disorders of apples such as bitter pit and internal breakdown have been associated with low levels of calcium in fruit tissues (10,11,13,14,21,23,29). DeLong (10) and Garman and Mathis (14) reported that apples from the 'Stark' and 'Baldwin' cultivars showing bitter pit symptoms were lower in calcium than fruit free of pit. Askew et al. (1) reported that discolored tissue was higher in total ash, Ca, Mg, K, Na, P and N than neighboring healthy tissue in 'Cox's Orange' apples affected with bitter pit.

In addition to low Ca content of fruit, high levels of K have been related to bitter pit incidence. In a two year survey of 'Northern Spy' apple orchards in Michigan, Oberly and Kenworthy (21) found that increased fruit K was associated with bitter pit incidence. Askew et al. (1), Garman and Mathis (14) and Martin (19) analysed bitter pit affected and non-affected fruit from 'Cox's Orange', 'Baldwin' and 'Sturmer' cultivars, respectively, and

concluded that fruit showing bitter pit symptoms had a higher K level when compared to fruit free of pitting. Also, these investigators showed a similar relationship with K/Ca ratios.

The application of calcium salts in the form of foliar sprays (5,6,8,11,14,26,30), fruit injections (5, 14) and fruit dips (14,26) have resulted in a reduction in the incidence of bitter pit.

Baxter (5) working in Australia, reported that six foliar applications of $Ca(NO_3)_2$ (.5%) to 'Cleopatra' apples would reduce bitter pit. The initial spray was applied in December. Applications to the leaves only, had no effect on pit incidence. Research in South Africa by Beyers (6) showed that four foliar applications of $Ca(NO_3)_2$ at a concentration of 1% beginning in December, to 'Golden Delicious' apples reduced both tree and storage pit but did not affect Ca content of the fruit. Drake _et al_. (11) obtained a highly significant correlation between Ca content of the peel of 'Baldwin' apple and bitter pit free fruit. They suggested that a peel content of .07% Ca would prevent bitter pit occurrence. Stevenson (30) applied 12 sprays of $Ca(NO_3)_2$ (.6%) to 'Granny Smith' apples in Australia. Bitter pit was significantly reduced in treated fruit. The Ca content of the peel was significantly increased with $Ca(NO_3)_2$ sprays but cortical tissue was not significantly altered. No other combinations of sprays

were used, therefore, it is not known which applications were the most effective. Injections of Ca acetate (5) and $Ca(NO_3)_2$ (14) into 'Cleopatra' and 'Baldwin' apple fruit, respectively, reduced bitter pit.

These various methods of calcium application usually result in an increase of Ca in the cortical region and peel of the fruit; hence the association of disorder appearance with low levels of Ca in the fruit.

Calcium salts which have resulted in the greatest reduction of bitter pit, when applied as foliar sprays, are $Ca(NO_3)_2$ and $CaCl_2$ with the former being widely used because of possible foliage injury with $CaCl_2$. These salts are usually applied as multiple applications in mid- to late-season with concentrations ranging from 3 to 10 lb/100 gallons (.36 to 1.2%).

The highest concentration of Ca in the fruit occurs after pollination and gradually decreases as the season progresses while total Ca content increases until maturity (25,31). The amount of Ca available to the fruit early in the season could be important and could conceivably determine the ultimate level of Ca in the fruit.

In view of current theories that low Ca levels in the fruit are associated with bitter pit (13) and that a predisposition to bitter pit is supposed to be decided early in fruit development (27), a series of experiments involving Ca sprays, were initiated in an attempt to alter Ca levels early in fruit development and reduce the occurrence of disorders. Nutrient-element investigations were conducted on fruit showing bitter pit symptoms. The microprobe was used in these studies.

Material and Methods

In 1969 experiments utilizing foliar Ca sprays were conducted on 'Northern Spy', 'Delicious' and 'Jonathan' cultivars. Two series of $Ca(NO_3)_2$ sprays (early and late season) were applied to mature 'Northern Spy' trees while only early season sprays were applied to the other two cultivars.

Early season sprays consisted of four $Ca(NO_3)_2$ applications at the rate of 5 lbs/100 gallons (.60%) with and without an equal amount of Rayplex*, a chelating compound. Dilute sprays were applied at weekly intervals beginning just prior to petal fall. Treatments and rates were the same for late season sprays applied at 2-week intervals beginning August 30, 33 days before harvest.

In addition to $Ca(NO_3)_2$ sprays, 2 late-season, dilute, $CaCl_2$ sprays were applied to 'Northern Spy' trees at the same time as the first 2 late-season $Ca(NO_3)_2$ sprays. Rates were 5 and 7 lbs/100 gallons (.60 and .84%) with and without an equal amount of Rayplex.

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*Rayplex, ITT Rayonier Incorporated, 161 East 42nd Street, New York, New York.

Treatments were applied to single tree plots with 2 replicates for 'Northern Spy' and 4 for 'Jonathan' and 'Delicious'.

On September 20, a random sample of 1 bushel of fruit from the 'Delicious' cultivar was picked for each treatment, weighed and placed in cold storage at 36F. On October 3, the same harvest procedure was followed for 'Jonathan' and 'Northern Spy'. Each bushel consisted of fruit picked from around the periphery of the tree. After 4 months, fruit of all cultivars were transferred to a 70F room for 2 weeks to allow for maximum development of disorders. Fruit of the 'Northern Spy' and 'Delicious' cultivars were examined for bitter pit; 'Jonathan' for internal breakdown.

Leaf samples were collected in July and October for early and late season sprays respectively for nutrient analysis. Nitrogen was determined by the Kjeldahl method, K by the flame photometer and P, Ca, Mg, Mn, Fe, Cu, B, Zn and Al spectrographically.

Chemical analysis of flesh and peel of representative samples of 40 fruit was performed for 'Northern Spy' and 'Delicious' while only flesh analysis was performed for 'Jonathan'. Fruit peel was obtained by using a hand peeler-corer apparatus. Cortex samples were obtained after peeling by combining 1/4 inch thick mean longitudinal wedges from each apple. The same elements were determined for these samples as for leaves, using the same procedures.

Chemical Investigations of Bitter Pit Tissue: 'Northern Spy' apples uniform in size with and without bitter pit symptoms were selected for electron microprobe analysis. Necrotic and adjacent normal appearing tissue of bitter pit affected apples and tissue of bitter pit free apples were compared for nutrient element composition. Cortical tissue was selected at the same morphological position for each apple.

Blocks consisting of cortical tissue, two centimeters cubed, were cut from each of 4 apples for analysis. The samples were dried and pressed into 1 1/4 inch boric acid discs at a pressure of 40,000 lbs/sq. in. for 30 seconds. The discs were then covered with carbon and surrounded with India ink to facilitate conductivity. Samples were analysed for relative amounts of K, Ca, Al, Mn, Mg, Fe and Cu. Tissues were also analysed for the non-essential elements Ba, Co, Pb, Rb, Sn, Sr, Ni, and Ti.

Results

Early season $Ca(NO_3)_2$ sprays did not significantly alter Ca levels in fruits or leaves nor did they reduce physiological disorders for any cultivar (Tables 1-5). 'Northern Spy' trees receiving the early season $Ca(NO_3)_2$ sprays without Rayplex show a significant lower level of K in leaves when compared to the other treatments (Table

TABLE 1.--The effect of four applications of $Ca(NO_3)_2$ at .60% during May and June on leaf and fruit composition of 'Northern Spy' apple (1969).

Plant Part Sampled	Treatment	% Dry Weight N	K	P	Ca	Mg
	Control	2.17	1.47a	.19	1.31	.29
Leaves	$Ca(NO_3)_2$	2.09	1.36 b	.20	1.31	.29
	$Ca(NO_3)_2$ + Rayplex	1.96	1.49a	.17	1.36	.29
		NS	*	NS	NS	NS
	Control	.30	.84	.077	.028	.025
Fruit Flesh	$Ca(NO_3)_2$	.34	.83	.071	.034	.030
	$Ca(NO_3)_2$ + Rayplex	.28	.85	.046	.023	.020
		NS	NS	NS	NS	NS
	Control	.54	.82	.092	.069	.093
Fruit Peel	$Ca(NO_3)_2$	.55	.80	.053	.023	.050
	$Ca(NO_3)_2$ + Rayplex	.52	.79	.059	.060	.070
		NS	NS	NS	NS	NS

NS = Not significant

*Significant (P .05)

Means followed by the same letter are not significantly different as determined by Duncan's multiple range test.

TABLE 2.--The effect of four applications of $Ca(NO_3)_2$ at .60% during May and June on leaf and fruit composition of 'Delicious' apple (1969).

Plant Part Sampled	Treatment	% Dry Weight				
		N	K	P	Ca	Mg
Leaves	Control	2.36	1.32	.169	1.22	.193
	$Ca(NO_3)_2$	2.28	1.30	.171	1.10	.179
	$Ca(NO_3)_2$ + Rayplex	2.30	1.16	.171	1.05	.172
		NS	NS	NS	NS	NS
Fruit Flesh	Control	.35	.887	.082	.043	.038
	$Ca(NO_3)_2$	.29	.793	.071	.018	.027
	$Ca(NO_3)_2$ + Rayplex	.34	.833	.090	.022	.028
		NS	NS	NS	NS	NS
Fruit Peel	Control	.84	.720	.092	.096	.119a
	$Ca(NO_3)_2$	.47	.597	.081	.068	.083b
	$Ca(NO_3)_2$ + Rayplex	.58	.593	.085	.100	.106ab
		NS	NS	NS	NS	**

NS = Not significant

**Significant (P .01)

Means followed by the same letter are not significantly different as determined by Duncan's multiple range test.

TABLE 3.--The effect of four applications of $Ca(NO_3)_2$ at .60% during May and June on leaf and fruit composition of 'Jonathan' apple (1969).

Plant Part Sampled	Treatment	% Dry Weight				
		N	K	P	Ca	Mg
Leaves	Control	2.44	1.12	.168	1.163	.187
	$Ca(NO_3)_2$	2.24	1.21	.164	1.016	.244
	$Ca(NO_3)_2$ + Rayplex	2.34	1.45	.158	1.120	.189
		NS	NS	NS	NS	NS
Fruit Flesh	Control	.024	.755	.064	.025	.022
	$Ca(NO_3)_2$	.023	.840	.064	.021	.016
	$Ca(NO_3)_2$ + Rayplex	.023	.855	.061	.040	.029
		NS	NS	NS	NS	NS

NS = Not significant

TABLE 4.--The effect of four applications of $Ca(NO_3)_2$ at .60% during May and June on bitter pit of 'Northern Spy' and 'Delicious' apples (1969).

Treatment	Weight (gm)	% Bitter Pit	Pits/Apple
	Northern Spy		
Control	168.0	12.1	19.7
$Ca(NO_3)_2$	170.6	17.3	6.4
$Ca(NO_3)_2$ + Rayplex	182.4	14.1	21.8
	NS	NS	NS
	Delicious		
Control	133.1	9.5	7.3
$Ca(NO_3)_2$	161.6	4.4	4.8
$Ca(NO_3)_2$ + Rayplex	154.4	5.6	5.6
	NS	NS	NS

NS = Not significant

TABLE 5.--The effect of four applications of $Ca(NO_3)_2$ at .60% during May and June on the incidence of internal breakdown in 'Jonathan' apples (1969).

Treatment	% Internal Breakdown
Control	5.9
$Ca(NO_3)_2$	7.3
$Ca(NO_3)_2$ + Rayplex	6.5
	NS

NS = Not significant

1). This is not considered to be a treatment induced effect but is probably due to the inherent variability of the trees.

None of the late season Ca salt sprays significantly altered the Ca content of fruit tissues, but there was a general increase in Ca content of peel with the $CaCl_2$ treatments, particularly when Rayplex was used (Table 6). The Ca content of leaves was significantly higher with respect to the $CaCl_2$ treatments (Table 7), however, considerable leaf scorch was prevalent. No significant differences in minor elements were detected for any spray treatment with regard to leaves and fruit.

Among the late season Ca salt spray applications, only the treatment $CaCl_2$ plus Rayplex significantly reduced the number of fruit exhibiting bitter pit (Table 7). Disorder severity, as indicated by pits per apple, was significantly reduced with the $Ca(NO_3)_2$ without Rayplex and both $CaCl_2$ treatments when compared to the control (Table 7). There was a tendency for all of the late season Ca treatments to reduce the number of pits per apple regardless of chemical formulation.

A brownish colored residue was present at harvest on leaves and fruit where Rayplex was added to the treatments. This was particularly evident for leaves and fruit with late season applications. This residue was difficult to remove from fruit using a water solution containing a strong detergent, Tide.

TABLE 6.--The effect of three applications of $Ca(NO_3)_2$ and two applications of $CaCl_2$ during August and September on the nutrient composition of 'Northern Spy' apples (1969).

Plant Part Sampled	Treatment	% Dry Weight N	K	P	Ca	Mg
Leaves	Control	2.49	1.16	.17	.91 b	.15
	$Ca(NO_3)_2$	2.38	1.27	.16	.88 b	.13
	$Ca(NO_3)_2$ + Rayplex	2.42	1.22	.17	1.00 b	.14
	$CaCl_2$	2.45	1.15	.16	1.15 a	.14
	$CaCl_2$ + Rayplex	2.42	1.16	.16	1.05 a	.14
		NS	NS	NS	*	NS
Fruit Flesh	Control	.33	.85a	.079	.035	.022
	$Ca(NO_3)_2$	.32	.79 b	.072	.014	.045
	$Ca(NO_3)_2$ + Rayplex	.31	.74 b	.080	.045	.042
	$CaCl_2$	.30	.82 b	.089	.022	.030
	$CaCl_2$ + Rayplex	.39	.93a	.086	.036	.032
		NS	*	NS	NS	NS
Fruit Peel	Control	.65	.79	.089	.099	.10
	$Ca(NO_3)_2$	.60	.75	.080	.065	.09
	$Ca(NO_3)_2$ + Rayplex	.60	.73	.094	.060	.07
	$CaCl_2$	.60	.65	.082	.110	.09
	$CaCl_2$ + Rayplex	.63	.88	.096	.200	.10
		NS	NS	NS	NS	NS

NS = Not significant

*Significant (P .05)

Means followed by the same letter are not significantly different as determined by Duncan's multiple range test.

TABLE 7.--The effect of three applications of $Ca(NO_3)_2$ and two applications of $CaCl_2$ on bitter pit of 'Northern Spy' apples (1969).

Treatment	Weight (gm)	% Bitter Pit	Pits/Apple
Control	188.25a	17.2a	9.7 b
$Ca(NO_3)_2$	183.82a	21.1a	2.4a
$Ca(NO_3)_2$ + Rayplex	157.60 b	17.5a	4.1ab
$CaCl_2$	180.12a	16.1a	1.2a
$CaCl_2$ + Rayplex	147.00 b	5.2 b	0.5a
	**	**	**

**Significant (P .01)

Means followed by the same letter are not significantly different as determined by Duncan's multiple range test.

In an attempt to relate some nutritional elements to the incidence of bitter pit, simple linear correlations between bitter pit and mineral composition of leaves and fruit (combining 'Northern Spy' and 'Delicious' cultivars) were determined. Included in the correlations were various ratios between Ca, Mg and K. No significant correlations were obtained between any expression of bitter pit and nutrient composition of leaves or fruit. The correlation between percent pit and fruit size was significant ($r = 0.55$). The same statistical procedure was used for 'Jonathan' in relation to internal breakdown. Again, no significant correlations were present.

Microprobe Investigations: Healthy cortical tissue of bitter pit affected apples when compared to tissue from non-affected apples was generally higher in all elements, with the exception of Mn and Ca which were lower, (Table 8). Those elements significantly higher for normal appearing tissue from pitted fruit were K, Cu and Al. The pitted tissue contained significantly higher amounts of Ca and Mg than adjacent normal appearing tissue or tissue of non-affected fruits.

Elemental ratios of K/Ca, (K + Mg)/Ca and Mg/Ca were higher in healthy tissue of pit affected apples when compared to non-affected apples (Table 8). K/Ca and (K + Mg)/Ca ratios were significantly higher in pitted tissue compared to non-affected apple tissue. The Mg/Ca ratio

TABLE 8.--The relative amounts of nutrient elements found in cortical tissue of 'Northern Spy' apple fruit with and without bitter pit as determined by microprobe analysis.

Source of Tissue	Counts/10 sec.						
	K	Ca	Mg	Mn	Fe	Cu	Al
From apples without pit	2461 b	151 b	32 b	26	84	25 b	58 b
From apples showing pit							
From tissues without pit	4396a	122 b	75 b	12	134	55a	293a
From tissues with pit	5771a	364a	443a	30	111	47a	281a
	**	*	**	NS	NS	*	**

	K/Ca	(K + Mg)/Ca	Mg/Ca
From apples without pit	17 b	17 b	.22 b
From apples showing pit			
From tissues without pit	46a	46a	.80ab
From tissues with pit	24ab	26ab	1.64a
	*	*	*

NS = Not significant

*Significant (P .05)

**Significant (P .01)

Means followed by the same letter are not significantly different as determined by Duncan's multiple range test.

was significantly higher in the pit affected fruit tissue when compared to non-affected apple tissue but did not significantly differ from adjacent tissue which appeared to be normal.

Analysis of each tissue for Ba, Co, Pb, Rb, Sn, Sr, Ni, and Ti was negative in that these elements were not present or the amounts present were not detectable.

Discussion

Early season $Ca(NO_3)_2$ sprays failed to reduce the incidence of physiological disorders in 'Northern Spy', 'Delicious' and 'Jonathan' fruit. The growing season of 1969 did not seem to be conducive for development of physiological disorders in apples as the incidence was low compared to other years. This low incidence of the disorders made comparisons of treatments difficult and in some instances the disorder was higher in treated plots than control (Tables 4, 5 and 7). Also, experimental results of other research work conducted over a period of years have been complicated by variation in years brought about by climatic conditions (20). In general, cool, wet seasons result in less physiological disorders than hot, dry seasons (32). The 1969 growing season was somewhat cool when compared to average Michigan conditions (12), particularly during May and June.

The Ca content of apple peel or cortex was not significantly altered with early or late season Ca salt sprays. Early season $Ca(NO_3)_2$ sprays have been shown to reduce bitter pit (16) but Ca content of the fruit was not determined. Also, the rates used (8 lbs/100 gallons or .96%) were higher than the rates used in this experiment and the percentage reductions in bitter pit associated with the sprays was higher than the controls reported herein. This may indicate that the reduction in bitter pit obtained with the use of $Ca(NO_3)_2$ sprays may be proportional to the severity of pit incidence since $Ca(NO_3)_2$ sprays have never been reported to eliminate the disorder. This was graphically illustrated in 6 years continuous research conducted by Martin using $Ca(NO_3)_2$ sprays (20).

The late season application of $CaCl_2$ + Rayplex significantly reduced bitter pit in 'Northern Spy' apples but did not result in complete elimination of the disorder. Ca content of the cortex was not appreciably higher than control fruit and was lower than the $Ca(NO_3)_2$ + Rayplex treatment. Furthermore, differences in bitter pit incidence did not seem to be related to Ca content of cortical tissue even though past research indicates that apples affected with the disorder have a low Ca level in the fruit (1,11,14,21). Others have reported that use of Ca salt sprays have not increased Ca in fruit flesh but significantly reduced bitter pit (11,17,30). This was the case with the $CaCl_2$ + Rayplex treatments in these experiments.

Ca content of fruit peel tissue has been implicated as the primary nutritional factor related to bitter pit incidence when compared to other fruit and plant parts sampled (11,17,30). $CaCl_2$ + Rayplex was the only treatment which significantly reduced bitter pit; and the Ca content of the peel was almost double the other treatments (Table 6).

Fruit size must be considered when discussing bitter pit, as larger fruit are generally more susceptible to pitting (5,13,18.20). Overall correlations, regardless of treatment, showed a positive correlation between percent pit and fruit weight indicating that fruit size was important in the apparent reduction of bitter pit by the $CaCl_2$ + Rayplex treatment since the lowest fruit weight was contained in this treatment. However, fruit weight was low also with respect to the $Ca(NO_3)_2$ + Rayplex treatment which did not have a low pit incidence. Furthermore, Ca content of peel from fruit treated with $CaCl_2$ + Rayplex was more than 3 times greater than the $Ca(NO_3)_2$ + Rayplex treatment indicating that Ca nutrition of the peel, rather than fruit weight, was the dominant factor in reduction of pit.

The severity of pit incidence as indicated by the number of pits per apple was reduced by all of the late season Ca sprays. The $CaCl_2$ sprays tended to be more effective than $Ca(NO_3)_2$ sprays which was probably due to a larger and more concentrated application of Ca. However, applications of Ca in the Cl form are questionable due to chance of leaf scorch especially at high temperatures.

Addition of Rayplex to $CaCl_2$ seemed to increase the effectiveness in reducing the severity of pit but had no effect with $Ca(NO_3)_2$. Previous use of chelating chemicals and surfactants failed to increase the effectiveness of any form of Ca used as a spray material (2,16,24).

Microprobe investigations confirmed the work of others that fruit affected with bitter pit have a lower Ca and higher K content than healthy fruit (1,10,11,14,17,19,22, 30). The higher ratios of K/Ca, Mg/Ca and (K + Mg)/Ca in pitted fruit (healthy tissue) indicate that a high level of K or Mg or low levels of Ca in the fruit could result in pit occurrence. Not only would the absolute levels of each element be important but a balance should be maintained among the 3 major cations. The effect of high Ca levels on reduction of pit could be overcome by abnormally large levels of K and Mg resulting in an increase in K/Ca and (K + Mg)/Ca ratios which would be conducive to pit development. Therefore, establishing a high Ca content of the fruit, without maintaining proper levels of K or Mg for a balanced situation, would be futile. In fact, indiscriminate use of K fertilizers has been implicated

as a possible cause for bitter pit and the idea that K may be the main operative nutritional element in bitter pit development (21). Invariably, K is always higher in fruit of pitted tissue in comparison to healthy tissue (1,3,14, 19,22).

There were relative high values of Ca, K and Mg present in necrotic tissues of affected apples. These elements could have accumulated as necrotic areas developed. However, artificially induced pitting does not contain high amounts of K, Mg or organic acids peculiar to naturally occurring pit (4). Another possible explanation for a high amount of these elements is that the pit may be manifested during early fruit development resulting in an abnormal metabolic functioning of cells. These abnormalities could prevent proper functioning of cells such as growth and absorption of nutrients, resulting in these elements being "physiologically trapped" in affected cells in early stages of fruit growth. Symptoms may not become present until late in the season when environmental stresses prevail. Anatomical studies have shown that abnormal growth of bitter pit cells may be indicative of some stress occurring early in the growth of the fruit (28).

Water relations and weather conditions play a major part in incidence of pitting (28,32). Conversely, mineral nutrition has been implicated as the primary area of importance in cause-effect relationships.

The role of Ca in reducing this disorder is not known. Ca is contained in the middle lamella as Ca-pectate and helps to strengthen cell walls. Ca also affects the permeability of cell membranes, and complexes with toxic compounds such as oxalic acid. An increased synthesis of organic anions could be the cause of pitting as an increase in total and titratable acidity is common to pitted tissue (4). Furthermore, Ca could complex with organic anions produced during periods of environmental stress during the fruit enlargement stage. Environmental stress agents, such as drought and high night temperatures, could result in synthesis or increased concentration of organic anions <u>via</u> respiration. Low levels of Ca in the fruit would not be able to remove the increased toxic anions and continue with other functions such as membrane permeability control.

Improper nutrient balance in the fruit is another possibility of a causal factor related to bitter pit incidence. This nutrient imbalance has been explained on the basis of ratios among the 3 major cations (Mg, K, Ca) in the fruit (1,3,14,19,20).

The most common ratio used in determining the nutrient imbalance phenomena is the (K + Mg)/Ca ratio. This ratio is much higher in pitted apples than in healthy ones. Bangerth (3) showed in a comparison of two susceptible cultivars that the (K + Mg)/Ca ratio in one cultivar (affected with pit) was higher than the other cultivar (no pitting present) but little difference in Ca was evident. This would again implicate K as the main operative element in bitter pit incident.

With respect to acid formation, excess K results in an excess production of acid, particularly citric acid (4, 9) which has been shown to increase soluble Ca in pitted tissue (15). This solubilization process may be depleting Ca from cell membranes or preventing Ca from performing other necessary physiological functions resulting in cell collapse or malfunction. Furthermore, this soluble Ca might translocate out of cells under conditions of moisture stress as Ca has been shown to move out of the apple under conditions of water stress (31).

Water supply and fruit temperature are two environmental factors which can be altered for practical use. Sprinkler irrigation systems have been used to reduce fruit temperatures, add water and reduce bitter pit (33). This effect could have been mediated by reducing respiration of fruit as fruit temperature was lowered from 10-20F.

Since treatments other than Ca sprays, dips and injections have been successful in reducing pit, perhaps a low level of Ca in the fruit is not the causal factor, but must be maintained in sufficient quantities during periods of environmental stress to prevent pitting. Investigations concerning environmental stress and fruit composition with

respect to bitter pit incidence demand further study before a definite single cause-effect relationship can be established, if one exists.

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EFFECT OF NUTRIENT AND GROWTH REGULATOR SPRAYS ON INTERNAL BREAKDOWN OF 'JONATHAN' APPLE FRUIT

Abstract: In 1970 experiments were designed to determine the effect of foliar applications of $Ca(NO_3)_2$, $MgSO_4$, K_2SO_4, SADH and TIBA on the nutrition and disorder incidence of 'Jonathan' apple trees and fruit. Three sprays of .60% $Ca(NO_3)_2$ applied at 2 week intervals beginning June 16 significantly reduced internal breakdown (IB) incidence of fruit during storage regardless of type of storage (CA or cold). K_2SO_4 sprays increased fruit K and were the only treatments influencing fruit composition values. However, some spray injury to leaves was prevalent. Addition of the adjuvant, Regulaid, to each of the nutrient spray treatments resulted in increased leaf absorption of the respective element.

Internal breakdown incidence was accentuated when harvest was delayed one week beyond the optimum harvest date. $Ca(NO_3)_2$ plus Regulaid reduced IB even when harvest was delayed. SADH and TIBA had no effect on IB when fruit were examined after 3 months of cold storage. SADH resulted in a firmer fruit at each harvest date. SADH resulted in a reduction of IB at the later harvest after fruit were kept in CA storage.

Simple linear correlations revealed that IB was negatively correlated with Ca and positively correlated with titratable acidity, fruit K/Ca, Mg/Ca and (K + Mg)/Ca ratios. There was a negative relationship between Ca and titratable acidity. Multiple correlations showed that Ca and titratable acidity was strongly related to IB at optimum harvest and water core was an important factor when harvest was delayed.

EFFECT OF NUTRIENT AND GROWTH REGULATOR SPRAYS ON INTERNAL BREAKDOWN OF 'JONATHAN' APPLE FRUIT

Introduction

In 1970 the 'Jonathan' cultivar represented approximately 27 percent of the total apple production in Michigan. 'Jonathan' is susceptible to numerous storage disorders in prolonged cold or controlled atmosphere (CA) storage. A major storage disorder is internal breakdown (IB) which is characterized by a light brown discoloration of the flesh near the skin and around vascular bundles and in severe cases the whole fruit may exhibit browning (7). Symptoms are usually present at the calyx end of the apple and in severe cases extends throughout the fruit. Delayed harvest, delayed cooling after picking and extending the storage period can result in IB.

IB has been related to the nutritional status of the tree and fruit (5,19,23,24,30). Bunemann _et al_. (5) found that 'Jonathan' fruit with highest incidence of IB had K contents considerably lower than the fruit from the trees yielding small quantities of fruit susceptible to IB.

Perring (23,24) concluded that fruit affected with IB was low in Ca and that a Ca content of 5 mg/100 gm fresh

weight in the flesh would prevent IB of 'Cox's Orange'. However, from further inspection of the data one might conclude that high K concentrations could be implicated as the causal element just as well as low Ca values.

Stebbins (30) after concluding a two year survey of 'Jonathan' apple orchards in Michigan concluded that either low fruit K or Ca was associated with IB incidence. Martin et al. (19) in Australia reported a negative correlation between IB and Ca content of the fruit in 'Jonathan' apples grown in pots.

Titratable acidity of apple fruit has been associated with IB incidence (12,15,18). Research in New Zealand by Letham (15) revealed that IB of 'Sturmer' apple fruit was positively correlated with titratable acidity. Haynes (12) found that there was a direct association between high titratable acidity and IB of 'Spalding Bramley's' apple fruit.

Nutrient sprays have been used to correct or reduce deficiencies in deciduous orchards for many years. Since IB has been related to the nutritional status of the fruit and tree, specifically with Ca and K, a series of sprays containing N, Ca, K and Mg and two growth regulators were evaluated for their effect on IB of 'Jonathan' fruit. Titratable acidity was measured also to determine its relationship to IB and mineral nutrition of the fruit.

Material and Methods

Two 'Jonathan' apple orchards in the mid-Michigan area with a previous history of IB incidence as described by Stebbins (23) were selected. Spray treatments consisted of $Ca(NO_3)_2$ (.60%), $MgSO_4$ (1.2%) and K_2SO_4 (1.9%); each of the separate treatments with and without the non-ionic adjuvant Regulaid[1] (.25%), $Ca(NO_3)_2$ plus urea (.60% + .36%), Succinic Acid 2,2-Dimethyl Hydrazide (SADH) (2000 ppm) and Triodobenzoic acid (TIBA) (50 ppm). The nutrient element treatments were applied as dilute foliar sprays 3 times at 2 week intervals beginning June 16, 1970. SADH and TIBA were applied only on the June 16 date. Treatments were duplicated on single tree plots in each orchard.

Leaf samples were collected from mid-terminal shoots at shoulder height from each tree on July 31. On October 5, two bushels of fruit were harvested from each tree at both locations. Each bushel container was lined with a plastic bag to minimize fruit moisture loss. One bushel was placed in cold storage at 36F and the other in controlled atmospheric (CA) storage at 32F with atmospheric concentrations of 3% O_2 and 5% CO_2. A 20-fruit sample was collected from each tree for weight, water core (WC), percent soluble solids, firmness, titratable acidity and

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[1]Formerly known as collodial SG, Collodial Products Corporation, Petaluma, California. Treatments including Regulaid will be designated with CSG following the chemical formula of salt used.

nutrient element determinations. Sampling procedures for nutrient element determinations of fruits were made as described by Perring (25). Two thin longitudinal sections were cut from each of 20 fruit, one each from the blushed and unblushed side of the fruit. A second harvest was made on October 12 and the storage procedures for the October 5 harvest were followed.

After 3 and 5 months, fruit were removed from cold and CA storage respectively, and placed in a warm room (70F) for two weeks to facilitate maximum development of IB symptoms. Removal of fruit from storage was sequential to harvest dates. From each bushel, 75 fruit were selected for inspection for various physiological disorders. Approximately 90 percent of fruit examined were 2 1/2 inches and larger.

Fruit removed from cold storage were examined for lenticel spot (LS) and IB while those removed from CA storage were examined for IB, core browning (CB) and brown heart (BH). To facilitate calculation of analysis of variance and to eliminate zeros in the data, an index number for disorder severity was used for each disorder except for lenticel spot which was calculated as percent of fruit affected. During examination, fruit were grouped into categories depending on disorder severity. Categories were as follows: 1 = none, 2 = trace, 3 = slight, 4 = moderate and 5 = severe. The number of fruit in each category was multiplied by the category number and then all categories were added together to produce an index number.

Fruit and leaf analyses were conducted using the following procedures: Nitrogen was determined by the Kjeldahl method, K by the flame photometer, and P, Ca, Mg, Mn, Fe, Cu, B, Zn and Al spectrographically (11).

The data were analyzed statistically as a split plot using orchards as a final split. For comparisons between harvest, data were analysed as a split plot design with harvest as sub plots. Simple linear correlations were determined for all parameters measured by combining parameter analysis for all trees regardless of location or treatment. Multiple correlations were conducted using a least squares delete procedure (8). Variables used in the final least squares equation were fruit parameters which showed significant linear correlations with the independent variable.

Results

Leaf composition values revealed that trees receiving the K_2SO_4 treatments had the highest K content which were significantly larger than the $Ca(NO_3)_2$ + CSG treatment where K was lowest (Table 1). Mg content was highest in leaves from trees receiving the $MgSO_4$ treatments. Only the $MgSO_4$ + CSG treatment was significantly greater than

TABLE 1.--Effect of nutrient and growth regulator sprays on leaf composition of 'Jonathan' apple trees sampled on July 31, 1970.

Treatment	% Dry Weight				
	N	K	P	Ca	Mg
Control	1.92	1.09ab	.24	1.35	.26a
$Ca(NO_3)_2$	1.93	1.01ab	.26	1.46	.26a
$Ca(NO_3)_2$ + urea	1.98	1.00ab	.29	1.48	.27a
$Ca(NO_3)_2$ + CSG	1.96	0.84a	.30	1.68	.31ab
$MgSO_4$	1.86	0.96ab	.26	1.50	.36ab
$MgSO_4$ + CSG	1.94	0.99ab	.30	1.63	.40 b
K_2SO_4	1.83	1.22 b	.27	1.51	.27a
K_2SO_4 + CSG	1.88	1.19 b	.41	1.69	.31ab
SADH	1.87	1.04ab	.29	1.72	.32ab
TIBA	1.88	1.08ab	.31	1.70	.28a

Means followed by the same letter are not significantly different at the 5% level.

the control. There were no significant differences in leaf N, P, Ca or the minor elements.

The addition of Regulaid to Ca, K and Mg sprays resulted in a slight but non-significant increase in leaf composition values for Ca, K and Mg.

The addition of Regulaid to K_2SO_4 and $MgSO_4$ sprays resulted in some leaf abnormalities. Leaves sprayed with $MgSO_4$ + CSG showed a slight marginal scorch which was not considered serious. One week following the initial K_2SO_4 + CSG application, leaves showed a complete yellowing with subsequent abscission. This symptom was randomly distributed throughout the tree. Later, symptoms appeared as circular necrotic spots distributed on the lamina but did not appear to be a nutrient toxicity or deficiency symptom since no consistent pattern of injury occurred.

Potassium was the only element which varied significantly in fruit composition (Table 2). Fruit from the control and K_2SO_4 treatment were significantly higher in K than fruit from any of the $Ca(NO_3)_2$, $MgSO_4$ or TIBA treatments.

Fruit at harvest showed no significant differences between treatments for weight (size), lenticel spot, water core, and soluble solids (Table 3). Titratable acidity was significantly lower in fruit from the $Ca(NO_3)_2$, $Ca(NO_3)_2$ + urea and TIBA treatments when compared to the $MgSO_4$ + CSG or SADH treatment (Table 3). The use of SADH resulted in a significantly firmer fruit at both harvest dates.

TABLE 2.--Effect of nutrient and growth regulator sprays on nutrient composition of 'Jonathan' apples harvested on October 5, 1970.

Treatment	% Dry Weight				
	N	K	P	Ca	Mg
Control	.23	.67a	.09	.07	.04
$Ca(NO_3)_2$	.22	.59 b	.08	.07	.04
$Ca(NO_3)_2$ + urea	.24	.61 b	.09	.07	.04
$Ca(NO_3)_2$ + CSG	.22	.60 b	.09	.07	.04
$MgSO_4$	.20	.59 b	.09	.06	.03
$MgSO_4$ + CSG	.20	.60 b	.10	.06	.03
K_2SO_4	.20	.68a	.10	.06	.04
K_2SO_4 + CSG	.20	.62ab	.10	.07	.04
SADH	.21	.62ab	.09	.06	.03
TIBA	.20	.58 b	.09	.06	.03

Means followed by the same letter are not significantly different at the 5% level.

TABLE 3.--Effect of nutrient and growth regulator sprays on weight, lenticel spot, titratable acidity, and soluble solids of 'Jonathan' apples harvested on October 5, 1970.

Treatment	Weight (gm)	% LS[1]	WC Index	TA	% SS	Firm. (lbs)
Control	105.58	16.50	47.4	9.84ab	12.2	17.80a
$Ca(NO_3)_2$	96.03	11.50	46.9	8.86a	11.8	17.22a
$Ca(NO_3)_2$ + urea	99.14	18.75	46.9	9.00a	12.0	17.30a
$Ca(NO_3)_2$ + CSG	94.48	12.75	42.9	9.52ab	12.2	17.42a
$MgSO_4$	97.59	11.75	48.2	9.47ab	12.5	17.50a
$MgSO_4$ + CSG	92.16	17.50	48.1	10.88 b	13.2	18.12a
K_2SO_4	99.30	13.00	44.4	9.89ab	12.0	16.95a
K_2SO_4 + CSG	90.81	12.75	46.9	10.18ab	12.6	18.00a
SADH	90.75	15.00	44.8	10.61 b	13.6	19.88 b
TIBA	87.15	15.25	44.5	8.74a	12.1	17.52a

Means followed by the same letter are not significantly different at the 5% level.

LS = Lenticel spot, WC = Water core, TA = Titratable acidity reported as meq./100 gm fr. wt., SS = Soluble solids.

[1]50 fruits were examined for each plot.

<u>Evaluation of Fruit Removed from Cold Storage</u>: The IB index and number of fruit exhibiting IB, for fruit harvested on October 5, was significantly reduced by each of the $Ca(NO_3)_2$ treatments when compared to the control or $MgSO_4$ treatment (Table 4). The $Ca(NO_3)_2$ treatment exhibited the greatest reduction in IB expressed as IB index, number of fruit affected or percent of control. By delaying harvest one week, only the $Ca(NO_3)_2$ + CSG treatment retained a significant effect in reducing IB incidence.

<u>Evaluation of Fruit Removed from CA Storage</u>: Examination of fruit harvested on October 5, showed that $Ca(NO_3)_2$ and $Ca(NO_3)_2$ + CSG treatments significantly reduced IB incidence when compared to the $MgSO_4$ and TIBA treatments (Table 5). Results were similar to those obtained from cold storage in that $Ca(NO_3)_2$ alone resulted in the greatest reduction of IB incidence. SADH had a moderate effect on reducing IB. A 1-week delay in harvest eliminated the significant reduction by Ca treatments at the first harvest. However, the $Ca(NO_3)_2$, SADH and $Ca(NO_3)_2$ + CSG treatments retained their relative effectiveness in reducing IB incidence.

Increased incidence of CB occurred with applications of $MgSO_4$ and TIBA when compared to $Ca(NO_3)_2$ and $Ca(NO_3)_2$ + CSG sprays (Table 6). The lowest incidence of the disorder was present in fruit from the $Ca(NO_3)_2$ + CSG treatment. Fruit from the SADH treatment had the lowest CB index when

TABLE 4.--Comparison of harvest date and nutrient and growth regulator sprays on internal breakdown (IB) of 'Jonathan' apples after 3 months of cold storage (36F) followed by 2 weeks at 70F.

Treatment	HARVEST DATES: October 5 Harvest			October 12 Harvest		
	Index	% of Control	Fruit No.[1]	Index	% of Control	Fruit No.[1]
Control	217.00 b	100.0	39.75 b	225.75 b	100.0	39.75 b
$Ca(NO_3)_2$	102.75a	47.4	9.00a	129.50ab	57.4	15.00ab
$Ca(NO_3)_2$ + urea	125.25a	57.7	14.00a	135.50ab	60.0	17.00ab
$Ca(NO_3)_2$ + CSG	107.25a	49.4	9.75a	116.25a	51.5	11.50a
$MgSO_4$	198.75 b	91.6	34.50 b	231.25 b	102.4	40.00 b
$MgSO_4$ + CSG	186.50ab	85.9	31.50 b	215.75ab	95.6	37.75ab
K_2SO_4	152.25ab	70.0	22.50ab	182.25ab	80.9	30.25ab
K_2SO_4 + CSG	151.00ab	69.6	21.75ab	210.50ab	93.2	35.50ab
SADH	161.00ab	74.2	25.00ab	213.25ab	94.5	20.38 b
TIBA	167.25ab	77.1	26.50ab	234.50 b	103.8	41.50 b

Means followed by the same letter are not significantly different at the 5% level.

[1]Total no. of fruit in breakdown index categories 3, 4 and 5. A definite browning was observed in each category.

TABLE 5.--Effect of nutrient and growth regulator sprays on internal breakdown (IB) of 'Jonathan' apples after 5 months in CA storage (32F) followed by 2 weeks at 70F.

Treatment	HARVEST DATES: October 5 Harvest			October 12 Harvest		
	Index	% of Control	No. of Fruit Affected[1]	Index	% of Control	No. of Fruit Affected[1]
Control	148.5ab	100.0	19.0ab	185.5	100.0	29.5ab
$Ca(NO_3)_2$	97.5a	65.6	6.2a	125.5	67.6	10.3ab
$Ca(NO_3)_2$ + urea	128.0ab	86.2	14.8ab	148.3	79.9	21.2ab
$Ca(NO_3)_2$ + CSG	98.5a	66.3	6.2a	112.5	60.6	8.2a
$MgSO_4$	185.0 b	124.6	29.3 b	202.0	108.9	33.5 b
$MgSO_4$ + CSG	119.8ab	80.7	12.0ab	125.5	67.7	14.0ab
K_2SO_4	140.2ab	94.4	17.5ab	157.5	84.9	20.8ab
K_2SO_4 + CSG	146.8ab	98.9	19.2ab	158.3	85.3	22.0ab
SADH	121.8ab	82.0	13.0ab	115.3	62.1	11.0ab
TIBA	193.0 b	130.0	27.5ab	163.5	88.1	23.5ab

Means followed by the same letter are not significantly different at the 5% level.

[1]Total no. of fruit in breakdown index categories 3, 4 and 5. A definite browning was observed in each category.

TABLE 6.--Effect of nutrient and growth regulator sprays on brown heart (BH) and core browning of 'Jonathan' apples after 5 months of CA storage (32F) followed by 2 weeks at 70F.

Treatment	HARVEST DATE							
	October 5				October 12			
	CB		BH		CB		BH	
	Index	No. of Fruit Affected	Index	No. of Fruit Affected	Index	No. of Fruit Affected	Index	No. of Fruit Affected
Control	122.5a c	31.2	79.0	2.0	183.2abc	42.7	96.8	8.2
$Ca(NO_3)_2$	111.3a	25.5	79.5	2.2	179.0abcd	41.0	100.3	7.5
$Ca(NO_3)_2$ + urea	146.5abc	39.0	86.8	4.5	203.8a	47.7	116.3	16.2
$Ca(NO_3)_2$ + CSG	106.8a	25.5	75.0	1.0	125.3 cd	29.5	82.3	4.0
$MgSO_4$	185.5 b	52.8	102.0	7.7	182.0ab	39.7	122.8	15.8
$MgSO_4$ + CSG	152.5abc	46.2	81.5	2.7	142.5abcd	30.7	94.8	6.5
K_2SO_4	140.0abc	41.2	76.5	1.0	137.0abcd	26.7	89.5	5.8
K_2SO_4 + CSG	147.8abc	46.0	77.0	1.2	128.2 bcd	16.2	84.0	4.2
SADH	134.8abc	38.5	75.0	1.0	111.2 d	20.0	82.0	2.5
TIBA	175.5 bc	42.7	85.8	4.0	197.8a	45.0	129.0	20.2

Means followed by the same letter are not significantly different at the 5% level.

BH = Brown heart, CB = Core browning.

harvest was delayed 1 week but was not significantly different from the $Ca(NO_3)_2$ + CSG treatment. The relationship between the $MgSO_4$, TIBA and $Ca(NO_3)_2$ treatments was similar to the first harvest.

Brown heart did not vary significantly among treatments but a greater occurrence was observed in fruit from the $MgSO_4$ treatment (Table 6).

A delayed harvest of 1 week accentuated the disorder incidence irrespective of disorder, treatment or type of storage (Table 7).

Simple Linear Correlations: Fruit showing water core symptoms had a positive correlation with leaf Mn and Al and a negative correlation with leaf K and fruit N, K and Cu at each harvest date (Tables 8 and 10). Also, water core determined on October 5 harvest date was negatively correlated with leaf Cu and on October 12 was negatively correlated with fruit Ca and Mn.

Fruit affected with lenticel spot were positively correlated with both leaf and fruit K, leaf Fe and fruit N, Cu, Zn, K/Ca, Mg/Ca and (K + Mg)/Ca and negatively correlated with leaf Mn, Al and fruit Fe (Tables 8 and 10).

No significant correlations occurred between fruit affected with internal breakdown and leaf nutrient elements. However, internal breakdown incidence showed a negative relationship with fruit Ca and a positive relationship with fruit K/Ca, Mg/Ca and (K + Mg)/Ca ratios at each harvest and with both storage operations (Tables 10 and 11).

TABLE 7.--Effect of delayed harvest on disorder incidence irrespective of treatments from both CA and cold storage.

Disorder	CA Storage Harvest Date		Cold Storage Harvest Date	
	Oct. 5	Oct. 12	Oct. 5	Oct. 12
IBI	137.95	149.4*	156.9	189.4**
IB No.[1]	16.45	19.4	23.7	30.4**
WCI[2]	44.8	47.3**		
WC No.	4.4	7.2**		
CBI	142.3	159.0*		
BHI	81.8	99.8**		

*Significant at the 5% level.

**Significant at the 1% level.

[1]Total of breakdown index categories 3, 4 and 5. A definite browning was observed in each category.

[2]Evaluated at harvest.

TABLE 8.--Significant correlation coefficients showing the association between leaf analysis and various physiological disorders of 'Jonathan' apples measured before or after cold storage (36F).

Element	Oct. 5 Harvest WC[1] Index	Oct. 5 Harvest % LS	Oct. 12 Harvest WC[1] Index
N			
K	-.527**	.716**	-.488**
P			
Ca			
Mg			
Mn	.655**	-.763**	.633**
Fe		.329*	
Cu	-.366*		
B			
Zn			
Al	.631**	-.724**	.626**

*Significant at the 5% level.

**Significant at the 1% level.

[1]Water core evaluated at harvest.

TABLE 9.--Significant correlation coefficients between leaf analysis and various disorders of 'Jonathan' apples after 5 months of CA storage (32F) followed by 2 weeks at 70F.

Element	Oct. 5 Harvest		Oct. 12 Harvest	
	Disorder Index			
	Brown Heart	Core Browning	Brown Heart	Core Browning
N				
K	-.443**		-.597**	-.557**
P				
Ca				
Mg				
Mn	.402**		.554**	.546**
Fe				
Cu		-.340*		
B				
Zn				
Al	.393*		.502**	.493**

*Significant at the 5% level.

**Significant at the 1% level.

TABLE 10.--Significant correlation coefficients showing the associations between fruit analysis and various disorders of 'Jonathan' apples after 3 months of cold storage (36F).

Element	October 5 Harvest			October 12 Harvest	
			Disorder Index		
	Internal Breakdown	Water[1] Core	Lenticel Spot	Internal Breakdown	Water Core
N		-.513**	.578**		-.363*
K		-.491**	.589**		-.383*
P					
Ca	-.521**			-.513**	-.360*
Mg					
Mn					-.415**
Fe			-.321*		
Cu		-.483**	.324*		-.375*
B					
Zn			.312*		
Al					
K/Ca	.549**		.366*	.348*	
Mg/Ca	.478**		.362*	.371*	
(K+Mg)/Ca	.553**		.357*	.354*	

*Significant at the 5% level.

**Significant at the 1% level.

[1]Evaluated at harvest.

TABLE 11.--Significant correlation coefficients showing the association between fruit analysis and various disorders of 'Jonathan' apples after 5 months of CA storage (32F) followed by 2 weeks at 70F.

Element	October 5 Harvest		Disorder Index	October 12 Harvest		
	Internal Breakdown	Brown Heart	Core Browning	Internal Breakdown	Brown Heart	Core Browning
N					-.396*	
K		-.471**			-.616**	-.517**
P						
Ca	-.501**		-.537**	-.436**		
Mg						
Mn						
Fe		.514**			.452*	
Cu			-.325*			
B						
Zn						
Al						
K/Ca	.444**			.415**		
Mg/Ca	.483**			.546**		
(K+Mg)/Ca	.451**			.425**		

*Significant at the 5% level.

**Significant at the 1% level.

The brown heart index calculated for fruit from the October 5 harvest was negatively correlated with both leaf and fruit K and positively correlated with leaf Mn, Al and fruit Fe (Tables 9 and 11). On the October 12 harvest date, brown heart incidence was positively correlated with leaf and fruit K and fruit N.

Fruit exhibiting core browning symptoms from the October 5 harvest showed a negative correlation with leaf and fruit Cu and fruit Ca (Tables 9 and 11). A 1-week delay in harvest resulted in core browning being negatively correlated with leaf and fruit K and positively correlated with leaf Mn and Al.

Internal breakdown incidence, when determined after 3 months of cold storage, showed a positive relationship with water core, titratable acidity and fruit weight regardless of harvest date (Table 12). There was a higher positive correlation between internal breakdown and water core with delayed harvest.

Water core incidence was negatively correlated with lenticel spot and positively correlated with firmness at both harvest dates. Additional positive correlations with water core after a delayed harvest were obtained with titratable acidity and fruit weight (Table 12).

Titratable acidity showed a positive relationship with fruit weight, firmness, and fruit K and a negative relationship with fruit Ca (Tables 12 and 13).

TABLE 12.--Significant correlation coefficients showing the association between various factors measured at harvest or after cold storage. Disorder indices were used in calculation of correlation coefficients.

Factor	IB[1]	IB[2]	WC[1]	WC[2]	% LS	TA	FW	Firm.
IB Oct. 5		.789**	.371*	.446**		.532**	.458**	
IB Oct. 12	.789**		.552**	.613**		.476**	.312*	.315*
WC Oct. 5	.371*	.552**		.826**	-.565**			.452**
WC Oct. 12	.446**	.613**	.826**		-.549**	.322*	.353*	.487**
% LS			-.565**	-.549**				-.511**
TA	.532**	.476**		.322*			.405**	.312*
FW	.458**	.313*		.353*		.405**		
Firm.		.315*	.452**	.487**	-.510**	.312*		

IB = Internal breakdown, WC = Water core, LS = Lenticel spot, TA = Titratable acidity, FW = Fruit weight, Firm. = Firmness.

[1]Evaluation associated with October 5 harvest.

[2]Evaluation associated with October 12 harvest.

*Significant at the 5% level.

**Significant at the 1% level.

TABLE 13.--Significant correlation coefficients showing the association between fruit analysis and parameter other than disorder incidence.

Element	Fruit Wt.	Firmness	% Soluble Solids	Titratable Acidity
N	.484**	-.377*	-.509**	
K	.512**	-.467**	-.402**	.385*
P				
Ca	-.310*			-.363*
Mg			-.624**	
Mn		-.414**	-.474**	
Fe				
Cu			-.343*	
B				
Zn		-.554**		
Al				

*Significant at the 5% level.

**Significant at the 1% level.

Correlations between fruit composition values and parameters other than disorder incidence revealed that fruit N and K were positively correlated with fruit weight and negatively with firmness and percent soluble solids (Table 13). A positive relationship occurred between K and titratable acidity. Additional negative correlations included fruit Ca with fruit weight, fruit Mn with firmness and percent soluble solids, Cu with percent soluble solids and Zn with firmness.

Correlations between disorders which developed after 5 months of CA storage revealed that core browning, internal breakdown and water core were positively correlated to each other (Table 14). Brown heart was positively correlated with water core determined at each harvest date and with fruit showing core browning from the October 12 harvest.

Discussion

Most of the treatments had a tendency to reduce IB incidence when compared to the control, but was especially evident with the $Ca(NO_3)_2$ sprays. Ca sprays have been reported to reduce IB incidence and other physiological disorders in apples (10,24). Even though Ca treatments resulted in a reduction of IB they did not appear to affect fruit Ca content as measured by spectrographic analysis. The Mg sprays were the least effective in reducing IB while K had an intermediate effect when considering the 3 major

TABLE 14.--Significant correlation coefficients showing the relationship between disorders from fruit examined after 5 months in CA storage (32F).

	CB^1	CB^2	IB^1	IB^2	WC^1	WC^2	BH^1	BH^2
CB^1		.746**	.680**	.516**	.484*	.558**	.470**	
CB^2	.746**		.342*	.444**	.696**	.677**	.542**	.343*
IB^1	.680**	.342*		.746**		.372*		
IB^2	.516**	.444**	.746**		.341*	.496**		.344*
WC^1	.484**	.696**		.340*		.826**	.636**	.669**
WC^2	.558**	.677**	.372*	.496**	.826**		.430**	.577**
BH^1		.542**			.636**	.430**		.823**
BH^2		.343*			.669**	.577**	.823**	

CB = Core browning, IB = Internal breakdown, WC = Water core, BH = Brown heart.

*Significant at the 5% level.

**Significant at the 1% level.

[1]Evaluation associated with October 5 harvest.

[2]Evaluation associated with October 12 harvest.

cations. This suggests that Ca is the major cation to be considered in a nutritional relationship with respect to IB. Further evidence for this relationship was shown with IB being negatively correlated with fruit Ca and positively correlated with K/Ca, Mg/Ca and (K + Mg)/Ca fruit ratios. These relationships suggest that an increase in fruit Ca or a decrease in fruit K or Mg would reduce internal breakdown. These relationships and analysis substantiate research of others with respect to analysis of fruit affected with IB (19,23,24,26,28,30).

It has been generally accepted that high levels of K in leaves or fruit would result in a reduced incidence of breakdown in affected fruits. This concept has been supported by soil applications (19,22) and survey data (5,30). However, there have been occasions when increased fruit K was associated with an increase in fruit breakdown (28,41). By virtue of simple correlations these experiments imply that K may be a possible cause or additional factor in relation to IB. Correlations with titratable acidity were most interesting in this respect. Normally, increased fruit K results in increased acid formation (34) and both were positively related in these experiments. Also, increased acidity was associated with increased incidence of IB. Conversely, Ca showed the reciprocal relationship to both acid and IB. In previous years titratable acidity of apple fruit has been associated with IB incidence (12,15, 18). Haynes (12) reported that there was a direct association between high titratable acidity and IB of 'Spalding Barmley's' apple fruit.

Other physiological disorders related to Ca shortages such as tipburn of lettuce and blossom end rot of tomatoes have been related to organic acid excess with Ca acting as a postulated neutralizing or complexing agent (9,32). The role of Ca in reducing IB is not clear but may be involved in organic anion metabolism similar to the above mentioned disorders.

Specific acids may be involved in abnormal metabolic functioning when IB occurs. Hulme _et al_. (13) reported that in air stored apples of 'Cox's Orange Pippin' there was a continuous rise in the oxaloacetic acid content and a rapid onset of low temperature breakdown as the acid reached its maximum level. When the fruit were warmed prior to storage both oxaloacetic acid and low temperature breakdown were reduced. This warming treatment has been reported to reduce IB in 'Bramley's Seedling' (31). Conversely, Wills and McGlasson (37) found no relationship with development of IB of 'Jonathan' fruit to oxaloacetic acid metabolism. Later work by Wills _et al_. (38) showed that high levels of acetic acid in 'Jonathan' fruit were associated with IB incidence. Injections of acetic acid into the fruit increased IB. In 1971 Wills and McGlasson (39) were able to reduce IB of 'Jonathan' fruit by warming them to 15C for 5 days. There was also a reduction in acetic acid with warming.

Clijsters (6) concluded that maleic acid was decarboxylated to acetaldehyde in apple flesh exhibiting breakdown symptoms. When maleic acid was added to fruit tissue acetaldehyde levels increased. Acetaldehyde injections into the fruit produced IB. Acetaldehyde has been shown to be very toxic to apple tissue (21). Since maleic acid is the predominant acid measured when titratable acidity is determined, increases in titratable acidity may result in increased acetaldehyde levels in fruits causing IB occurrence. Also, this may indicate that high K content of the fruit may be an additional cause of IB since K is directly associated with titratable acidity (34).

Multiple correlations using a least squares delete procedure, with IB as the dependent variable resulted in titratable acidity and Ca being the most important factors contributing to IB incidence (Table 15) and were negatively correlated with each other. Further delineation by use of multiple correlations with titratable acidity as the dependent variable suggest that a decrease in acidity could be manifested by maintaining proper Ca levels in the fruit (Table 15). The exact amounts of Ca needed in a fruit to prevent excess acidity is not known but flesh Ca content of 5 mg/100 gm fresh weight will supposedly prevent breakdown

TABLE 15.--Multiple correlation and regression coefficients with internal breakdown and titratable acidity as dependent variables.

Dependent Variable	Independent Variables	Regression Coefficients	Partial Correlation Coeff.	r	r^2	Sig
		October 5 Harvest				
Internal Breakdown	Constant	101.43		.64	.41	*
	Fruit Ca	-2235.62	-.41			
	Titratable Acidity	21.30	.43			
		October 12 Harvest				
Internal Breakdown	Constant	110.31		.69	.47	*
	Fruit Ca	-2435.39	-.40			
	Water core	5.15	.53			
Titratable Acidity	Constant	11.37		.84	.71	**
	Fruit Ca	-25.46	-.84			

*Significant at the 5% level.

**Significant at the 1% level.

in 'Cox's Orange Pippin' (18). In the experiments reported herein only 1 tree out of 40 had a fruit Ca content below .05% or 500 ppm. However, both peel and flesh were analysed for each sample which would tend to result in a higher Ca content compared to flesh analysis alone.

One of the most important factors to be considered when discussing IB is fruit weight or size. Large sized fruit tend to result in an increased fruit susceptibility to physiological disorders (14,18,19,27,30). Increases in fruit size may be accompanied by increased K, Mg and titratable acidity (18,19,27,30) but may not have the effect of increased Ca. In fact, increase in fruit size would have a tendency to reduce Ca concentration; thereby reducing the apparent beneficial Ca effect in reducing disorders. This relationship was shown by the negative correlation of fruit weight and Ca (Table 13). If the assumptions with titratable acidity are valid and the effect of fruit size on K and Ca is justified, it would seem that a balance of K and Ca would be desirable to maintain a crop of sound fruit. Cultural practices such as thinning, pruning and K application should be regulated in this respect. By using $Ca(NO_3)_2$ sprays the Ca content of fruit may have been sufficiently altered to ensure a desirable balance of the 3 major cations.

Large fruit not only affect nutrient balance but alters maturity. In general, increased fruit size will

hasten maturity and increase respiration rates of fruits. Therefore, harvesting fruit at the proper time is essential when crop load is light. However, with 'Jonathan' there is a tendency to leave the fruit on trees for color development, which could result in fruit becoming more susceptible to breakdown. A 1-week delay in harvest resulted in increased disorder incidence (Table 7). When harvest was delayed the $Ca(NO_3)_2$ + CSG sprays retained their relative effectiveness in reducing IB.

Environmental conditions can also have an effect on the quality and composition of apple fruit. High night temperatures (68F) during the final 44 days of fruit maturity have increased the titratable acidity of 'Stayman' apples (1). In the latter part of the season Ca may move out of fruit particularly if conditions are favorable for high transpiration rates to occur (36). It appears that environmental conditions may be just as important as nutrition in the development of IB. However, adequate Ca levels must be maintained in fruit to prevent excessive breakdown. It is possible that this effect of Ca may be mediated by complexing with toxic organic anions (acids) produced by fruits under environmental stress.

The relationship of water core to various disorders was consistent in that positive correlations occurred (Table 14). Correlations between other disorders, excluding water core, were not consistent which suggests that

water core or conditions conducive for water core development may be a predisposition to these physiological disorders. This concept has been thoroughly examined for internal breakdown with water core (16,17,28,30) and almost always water core was related to internal breakdown incidence.

Factors which contribute to water core development are maturity, temperature, sorbitol and orchard practices. More mature fruit is likely to have more severe water core. This was true in these experiments (Table 7). If a delay in harvest results in increased water core, a concomitant increase in IB should occur. This happened in these experiments as denoted by an increase in correlation coefficients when harvest was delayed 1 week. Fruit exposed to sunlight and high temperatures have been found to develop water core quickly and intensely (4). Sorbitol is one of the major translocatable carbohydrates in apple leaves and has been associated with water core development (40). Williams (40) reported that water cored tissue of 'Delicious' apples was higher in sorbitol than adject non-water cored tissue. Also, as sorbitol decreased in leaves it increased in the fruit.

Smagula et al. (29) reported that apple tissue showing water core conditions was higher in acetaldehyde, ethanol and ethylacetate than adjacent non-water cored tissues and persisted in the fruit if water core disappeared.

Subsequently browning occurred following water core. These results are consistent with Clijsters (6) who found that acetaldehyde accumulation in 'Jonathan' fruit resulted in IB symptoms. Also, multiple correlations showed that water core became a significant factor in IB development when harvest was delayed (Table 15). Ca sprays have been reported to reduce water core (3). This would support the negative correlation between water core and Ca reported herein. It would seem that conditions conducive for high photosynthesis activity may be an important factor in WC development and subsequent IB incidence.

This suggests that nutritional factors may be secondary to environmental stress factors in regard to the occurrence of physiological disorders. Environmental stress factors that tend to increase respiration, in the balance of photosynthesis-respiration, would tend to increase titratable acidity and thereby increase the incidence of disorders. Control of these stress factors may prove to be as critical as control of nutritional conditions.

The correlations obtained with leaf analysis were considered to be of little importance since the fruit was the plant part exhibiting symptoms. However, leaf N should be used in assessing tree vigor. Correlations between leaf and fruit analysis resulted in only 2 correlations being significant (Mn, r = -.56, K, r = +.82).

In general there was a lower incidence of IB in fruit from CA storage than from cold storage and SADH had a ubstantial effect in reducing IB. This may be attributed o a lower respiration rate and a delay in the natural enescence of the fruit.

In conclusion, it appears that to establish a cause-ffect relationship for future control of IB is difficult. ruit nutrient composition, fruit size, fruit maturity, ater core incidence and environmental conditions play an mportant part in causes of IB. Most of these factors are nterrelated, with fruit size being an important feature. ncreases in fruit size affect the nutrient balance in the ruit and are conducive to water core development. Exces-ive tree vigor caused by thinning, light crops, heavy runing or excessive N applications contribute substan-ially to IB. Improved storage performance may, therefore, e obtained by suitable adjustment of cultural practices nd use of supplementary Ca sprays.

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TABLE A-1.--Leaf composition values of 'Jonathan' trees from the Ray Klackle orchard, Belding, Michigan collected July 31, 1970.

Treatment	N (%)	K (%)	P (%)	Ca (%)	Mg (%)	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Control	1.96	1.00	.27	1.42	.22	163	112	10	33	19	328
Control	1.96	.78	.23	1.52	.31	174	77	9	26	17	290
$Ca(NO_3)_2$	1.96	.68	.29	2.02	.31	192	130	6	32	14	379
$Ca(NO_3)_2$	1.82	.64	.28	1.42	.27	179	83	4	27	9	328
$Ca(NO_3)_2$ + urea	1.94	.90	.39	1.75	.27	194	130	6	28	13	354
$Ca(NO_3)_2$ + urea	1.88	.54	.26	1.54	.25	174	100	4	26	10	316
$Ca(NO_3)_2$ + CSG	2.00	.78	.32	1.65	.25	214	183	6	28	16	543
$Ca(NO_3)_2$ + CSG	1.84	.68	.32	1.93	.30	179	100	9	30	16	354
$MgSO_4$	2.00	.86	.23	1.61	.33	148	106	3	28	5	366
$MgSO_4$	1.84	.44	.24	1.70	.36	153	71	3	24	9	315
$MgSO_4$ + CSG	1.92	.82	.38	1.84	.36	161	112	3	32	8	366
$MgSO_4$ + CSG	1.98	.68	.31	1.70	.39	214	100	4	30	10	404
K_2SO_4	1.92	1.00	.30	1.52	.24	163	124	3	29	8	416
K_2SO_4	1.80	.78	.26	1.79	.31	137	83	7	29	10	290
K_2SO_4 + CSG	1.78	.90	.33	1.52	.22	163	130	6	29	10	404
K_2SO_4 + CSG	1.90	1.00	.43	1.61	.28	153	88	6	30	10	328
SADH	1.76	.50	.29	1.70	.25	169	144	5	31	10	416
SADH	1.80	.64	.36	1.82	.28	214	94	10	29	13	340
TIBA	1.96	1.00	.46	1.42	.22	189	130	4	32	10	404
TIBA	1.94	.68	.29	1.79	.25	169	88	6	30	10	340

TABLE A-2.--Leaf composition values of 'Jonathan' trees from the John Schaefer orchard, Sparta, Michigan collected July 31, 1970.

Treatment	N (%)	K (%)	P (%)	Ca (%)	Mg (%)	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Control	1.90	1.20	.24	1.15	.24	28	77	7	33	10	101
Control	1.88	1.36	.23	1.29	.25	45	135	7	29	13	88
$Ca(NO_3)_2$	1.92	1.26	.23	1.12	.22	23	106	23	27	8	101
$Ca(NO_3)_2$	2.02	1.46	.26	1.29	.25	45	100	6	28	8	120
$Ca(NO_3)_2$ + urea	2.02	1.26	.25	1.33	.31	34	100	15	30	10	101
$Ca(NO_3)_2$ + urea	2.10	1.30	.25	1.29	.25	43	112	7	28	6	120
$Ca(NO_3)_2$ + CSG	2.08	.94	.28	1.61	.38	40	94	5	29	10	114
$Ca(NO_3)_2$ + CSG	1.92	.94	.28	1.52	.33	42	230	6	29	10	114
$MgSO_4$	1.86	1.26	.32	1.31	.38	23	212	4	28	17	114
$MgSO_4$	1.78	1.30	.26	1.38	.36	40	100	3	28	16	126
$MgSO_4$ + CSG	1.96	1.36	.25	1.38	.41	17	177	4	30	10	113
$MgSO_4$ + CSG	1.90	1.10	.28	1.61	.43	29	112	4	26	13	126
K_2SO_4	1.94	1.58	.27	1.38	.28	40	395	7	32	10	126
K_2SO_4	1.68	1.52	.28	1.33	.24	40	247	4	32	16	126
K_2SO_4 + CSG	2.04	1.26	.29	1.61	.30	28	106	7	30	18	88
K_2SO_4 + CSG	1.78	1.62	.60	2.02	.43	45	153	13	38	21	164
SADH	2.06	1.36	.24	1.52	.35	34	159	7	30	10	101
SADH	1.86	1.68	.26	1.84	.39	28	165	7	33	10	114
TIBA	1.90	1.16	.24	1.75	.37	40	312	7	30	13	88
TIBA	1.70	1.48	.25	1.84	.28	17	112	1	24	5	107

TABLE A-3.--Fruit composition values of 'Jonathan' apple fruit harvested from the Ray Klackle orchard, Belding, Michigan collected October 5, 1970.

Treatment	N (%)	K (%)	P (%)	Ca (%)	Mg (%)	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Control	.28	.68	.09	.04	.04	3	24	4	20	1	38
Control	.18	.56	.08	.08	.04	4	13	5	17	2	13
$Ca(NO_3)_2$	.22	.64	.08	.05	.04	3	45	2	16	1	16
$Ca(NO_3)_2$	.18	.42	.09	.08	.04	4	47	3	16	1	19
$Ca(NO_3)_2$ + urea	.20	.58	.10	.07	.04	4	56	1	16	6	13
$Ca(NO_3)_2$ + urea	.18	.42	.08	.07	.03	2	51	2	18	3	13
$Ca(NO_3)_2$ + CSG	.20	.52	.09	.07	.04	3	65	4	14	3	25
$Ca(NO_3)_2$ + CSG	.18	.50	.10	.08	.04	4	53	5	20	4	22
$MgSO_4$	.18	.56	.09	.07	.04	8	239	5	16	4	19
$MgSO_4$	.20	.38	.08	.07	.03	7	67	5	17	2	13
$MgSO_4$ + CSG	.18	.58	.11	.07	.04	4	41	4	14	3	16
$MgSO_4$ + CSG	.16	.48	.10	.07	.02	6	59	4	18	3	22
K_2SO_4	.22	.56	.09	.07	.04	3	46	3	15	2	16
K_2SO_4	.16	.58	.10	.07	.04	3	49	3	18	5	9
K_2SO_4 + CSG	.18	.54	.10	.07	.04	4	79	4	15	3	22
K_2SO_4 + CSG	.16	.52	.10	.08	.04	4	50	4	18	2	19
SADH	.18	.62	.10	.05	.02	1	60	3	16	1	13
SADH	.18	.46	.09	.07	.04	4	54	4	17	2	14
TIBA	.18	.56	.11	.07	.04	9	227	6	21	3	19
TIBA	.16	.44	.08	.07	.03	9	250	5	18	3	19

TABLE A-4.--Fruit composition values of 'Jonathan' apples harvested from the John Schaefer orchard, Sparta, Michigan collected October 5, 1970.

Treatment	N (%)	K (%)	P (%)	Ca (%)	Mg (%)	Mn ppm	Fe ppm	Cu ppm	B ppm	Zn ppm	Al ppm
Control	.22	.72	.12	.08	.04	9	241	7	23	3	13
Control	.24	.72	.08	.08	.04	7	14	8	18	7	28
$Ca(NO_3)_2$	.22	.60	.07	.08	.03	6	12	5	17	6	13
$Ca(NO_3)_2$	.24	.70	.08	.08	.04	7	10	7	17	4	13
$Ca(NO_3)_2$ + urea	.26	.70	.08	.08	.04	7	13	7	20	4	19
$Ca(NO_3)_2$ + urea	.30	.74	.09	.08	.04	8	15	8	18	5	16
$Ca(NO_3)_2$ + CSG	.26	.68	.09	.07	.04	6	53	6	18	4	13
$Ca(NO_3)_2$ + CSG	.22	.68	.08	.07	.04	6	12	5	18	3	11
$MgSO_4$	.24	.72	.10	.05	.04	6	53	6	14	3	9
$MgSO_4$	.20	.70	.09	.07	.04	7	48	7	19	3	19
$MgSO_4$ + CSG	.22	.64	.08	.07	.03	6	48	6	20	3	9
$MgSO_4$ + CSG	.22	.68	.10	.05	.04	6	47	7	16	2	13
K_2SO_4	.22	.80	.10	.05	.03	6	43	5	18	5	12
K_2SO_4	.22	.80	.10	.07	.04	7	50	6	19	6	16
K_2SO_4 + CSG	.22	.72	.10	.07	.04	6	65	7	20	3	16
K_2SO_4 + CSG	.26	.70	.10	.07	.04	6	43	7	16	3	13
SADH	.22	.70	.07	.05	.03	4	43	12	12	2	13
SADH	.26	.72	.09	.07	.04	6	28	14	18	3	16
TIBA	.24	.66	.08	.05	.03	4	44	20	14	3	16
TIBA	.22	.64	.07	.07	.03	6	6	4	13	3	16

TABLE A-5.--Internal breakdown and water core incidence of fruit harvested on October 5, 1970 and placed in cold storage (36F) followed by 2 weeks at 70F.

Treatment	Klackle IB Index	Klackle No. Affect. Fruit	Klackle WC[1] Index	Klackle No. WC	Schaefer IB Index	Schaefer No. Affect. Fruit	Schaefer WC[1] Index	Schaefer No. WC
Control	319	62	50	10	137	22	41	1
Control	281	55	50	9	131	20	40	1
$Ca(NO_3)_2$	101	9	49	9	84	4	40	1
$Ca(NO_3)_2$	107	10	48	8	119	13	41	1
$Ca(NO_3)_2$ + urea	204	35	52	12	81	2	40	1
$Ca(NO_3)_2$ + urea	81	2	47	7	135	17	40	1
$Ca(NO_3)_2$ + CSG	95	8	43	1	84	3	41	1
$Ca(NO_3)_2$ + CSG	82	3	40	4	168	25	44	4
$MgSO_4$	209	38	55	3	266	53	41	1
$MgSO_4$	163	24	48	6	209	38	44	4
$MgSO_4$ + CSG	205	35	51	11	175	31	44	4
$MgSO_4$ + CSG	115	12	52	6	199	33	43	3
K_2SO_4	134	17	44	4	231	44	44	4
K_2SO_4	88	5	43	3	156	24	43	3
K_2SO_4 + CSG	191	32	48	8	148	20	41	1
K_2SO_4 + CSG	115	12	48	8	150	23	41	1
SADH	180	30	44	2	222	41	43	3
SADH	129	16	42	5	113	13	42	2
TIBA	118	13	45	5	163	26	40	1
TIBA	182	28	47	5	206	39	42	2

[1]Water core was evaluated at harvest.

TABLE A-6.--Internal breakdown incidence of fruit harvested on October 5, 1970 and placed in CA storage (32F) followed by 2 weeks at 70F.

Treatment	Klackle		Schaefer	
	IB Index	No. Affect. Fruit	IB Index	No. Affect. Fruit
Control	253	46	151	21
Control	89	4	95	5
$Ca(NO_3)_2$	87	3	86	3
$Ca(NO_3)_2$	106	10	111	9
$Ca(NO_3)_2$ + urea	157	22	92	5
$Ca(NO_3)_2$ + urea	172	28	91	5
$Ca(NO_3)_2$ + CSG	86	3	88	8
$Ca(NO_3)_2$ + CSG	76	1	144	18
$MgSO_4$	218	36	182	29
$MgSO_4$	137	19	203	33
$MgSO_4$ + CSG	151	19	115	11
$MgSO_4$ + CSG	102	8	111	10
K_2SO_4	103	9	241	44
K_2SO_4	98	6	119	13
K_2SO_4 + CSG	245	46	105	9
K_2SO_4 + CSG	105	7	132	15
SADH	81	2	214	39
SADH	79	1	113	10
TIBA	167	9	252	45
TIBA	158	23	197	33

TABLE A-7.--Variation in fruit and leaf nutrient elements for overall Jonathan experiment--2 orchards (40 trees), 1970.

Element	Fruit			Leaf		
	Std. Dev.	Mean	Coeff. Var. %	Std. Dev.	Mean	Coeff. Var. %
N% dry wt	.035	.210	16.4	.100	1.91	5.2
K% dry wt	.108	.620	17.4	.335	1.04	32.2
P% dry wt	.011	.090	12.2	.072	2.96	2.4
Ca% dry wt	.010	.068	14.7	.228	1.57	14.5
Mg% dry wt	.005	.036	13.9	.062	.30	20.7
Mn ppm	1.960	5.380	36.4	73.440	104.69	70.0
Fe ppm	63.160	60.790	103.9	65.920	134.81	48.9
Cu ppm	3.328	5.650	58.9	3.860	6.54	59.0
B ppm	2.129	17.387	12.2	2.530	29.49	8.6
Zn ppm	1.515	3.147	48.1	3.780	11.68	32.4
Al ppm	5.528	16.258	34.0	134.180	238.51	56.3