GROWTH AND LEAF COMPOSITION IN RELATION TO THE SUPPLY OF CHLORIDE AND SULFATE ANIONS TO CHERRY, APPLE, PEACH AND GRAPE PLANTS

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David Ross Dilley
1957

THESIS

GROWTH AND LEAF COMPOSITION IN RELATION TO THE SUPPLY OF CHLORIDE AND SULFATE ANIONS TO CHERRY, APPLE, PEACH AND GRAPE PLANTS.

By

DAVID ROSS DILLEY

AN ABSTRACT

Submitted to the College of Agriculture of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

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1957

Approved..........A. L. Kenworthy..........

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G 987

David Ross Dilley

ABSTRACT

The specific influence of chloride and sulfate anions, used singly and in combination, upon growth and leaf composition of Montmorency cherry, Delicious apple, and Elberta peach, and Concord grape was studied by the means of nutrient solution methods.

Three levels of chloride and sulfate were employed in a factorial design giving nine treatment combinations without altering the metallic cation content of Hoagland's nutrient solution.

Growth was measured as linear growth of shoots and dry weight of various plant parts - leaves, shoots, fibrous roots, and trunk. Increase in total dry weight was calculated. Leaves from each tree and stems from each grape plant were analyzed for twelve elements: nitrogen, phosphorus, potassium, calcium, magnesium, iron, boron, manganese, copper, zinc, sulfur and chlorine.

Increasing the supply of chloride decreased all measurements of growth for all crops and produced leaf symptoms on peach and grape.

Increasing the sulfate supply did not adversely affect the growth of apple, peach, and grape; but depressed growth of cherry trees.

Increasing the supply of chloride and sulfate together depressed growth in proportion to the chloride level.

The chloride content in cherry leaves and grape petioles was directly proportional to supply. Apple and peach leaves contained more chloride when supplied with a medium chloride level. Increasing the sulfate level apparently reduced chloride absorption for all crops.

Sulfur content in all plants increased with supply in the absence of chloride. High chloride levels depressed sulfate absorption for all crops.

Moderate and high chloride levels depressed potassium absorption in cherry, apple and peach while high levels of chloride increased potassium in grape. Sulfate did not reduce potassium absorption in any crop.

Increasing the level of chloride in the solution increased nitrogen in peach and grape; manganese in cherry, apple and peach; copper and zinc in grape; and decreased; potassium in cherry, apple and peach; calcium in cherry and peach; magnesium in peach and grape; and boron in cherry.

Increasing the sulfate level in the solution increased nitrogen in peach; phosphorus in cherry and peach; iron in peach and grape; boron in cherry, apple and peach. Higher levels of sulfate decreased calcium in cherry, apple and peach; and zinc in peach and grape.

Chloride and sulfate in combination increased nitrogen in peach and phosphorus in cherry and decreased calcium in cherry and peach more than when applied separately. Iron content in apple and zinc content in grape was depressed more when chloride and sulfate were supplied in combination than when applied singly.

Although growth depressions for all crops with increasing chloride or sulfate in the nutrient solution was of the same magnitude, this could not be attributed solely to the concentration of chloride in the leaves. The low or high level of certain elements induced by chloride or sulfate levels were not considered inadequate nor toxic for growth according to field observations. However, the relative proportions of certain elements in the leaves induced by unequal anion supply and absorption may have been a factor causing reduction in growth. Conversely, the accumulation of certain ions in the leaves may have been the result of reduced growth and not necessarily the result of absorption as influenced by chlorides.

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INTRODUCTION

Depletion of potassium reserves in the soil through cropping eventually leads to the addition of potassium fertilizers to maintain profitable crop yields. In certain instances the use of quantities in excess of a thousand pounds per acre are common. When applications reaching this magnitude are used consideration of the associated "inert ingredients" or anion supplied with potassium becomes increasingly important

Recognizing the harmful effects of "inert ingredients" or anion many tobacco and blueberry producers no longer include potassium chloride in their fertilizer programs due to adverse side-effects of the associated chloride ion. Other crops such as beets can tolerate large amounts of chloride without hurting crop yields.

Potassium fertilizers are becoming more generally used to satisfy the requirements of fruit crops in most production areas. The use of greater quantities of potassium fertilizers in fruit plantings may eventually expose detrimental effects of the "carrier" components. Some components may be beneficial, some detrimental, while still others may not influence plant growth and quality.

The purpose of this experiment was to determine the specific effects of chloride and sulfate anions, two common "carrier" components in potassium fertilizers, as related to vegetative growth and leaf tissue composition of Montmorency cherry, Delicious apple, and Elberta peach trees, and Concord grape plants.

REVIEW OF LITERATURE

The importance of sulfur as a plant nutrient is generally known and accepted. Chlorine, on the other hand, has been considered nonessential. However, beneficial effects of chloride have been reported by Eaton (13) in the nutrition of cotton and tomatoes. Young (60), Lipman (34), and Schmalfuss (51) report beneficial effects of chloride with a wide number of plants. Recently, Broyer (6) established the essentiality of chloride in the nutrition of higher plants. Arnon (2) reports intact green cells can carry on photosynthesis without the participation of chloride. However, once the cells are broken, there is a rapid light induced deterioration of some cellular substance essential for photosynthesis. Chloride ion protects this substance against inactivation while the intact cell accomplishes this in some other manner.

While chloride has been found beneficial in various concentrations to certain crops, other crops have been injured by chloride. Kelly (29) and Reifenberg (47) found citrus trees were injured by a chloride concentration above 200 p. p. m. in irrigation water. Kelley and Thomas (28) observed excess chloride in the soil caused scorching and defoliation of citrus leaves. Tip-burn and mottling of citrus leaves occurred in a nutrient solution containing 710 p. p. m. of chloride, according to Chapman and Liebeig (9). Haas (20) reported that healthy orange leaves contained 0. 48 per cent chloride (dry weight basis) whereas leaves from injured trees contained 3. 48 per cent chloride.

Boresch (5) found the use of chloride fertilizer blighted the edges of currant leaves. Similar reports relate chloride accumulation to leaf scorch in avocado, Haas (18) and pecan, Harper (22).

Deterioration of grape vines growing on saline soil was reported by Ravikovitch and Bidner (46) due to high chloride content found in leaves from affected vines (2.47 per cent on dry weight basis) as compared to low chloride concentrations (0.15) per cent) found in the leaves from healthy vines. Thomas (55) reported that grapes growing on saline soil were afflicted with premature opening of buds, small leaves and fruit, defoliation, and, in extreme cases, faulty fruit set. Marginal and interveinal necrosis were symptoms of chloride toxicity appearing on leaves.

Jacobs et. al. (25) found the addition of 150 pounds per acre of potassium chloride injurious to leaves on young orange shoots, whereas the same rate of potassium as sulfate was not injurious.

Parups (42), working with Montmorency cherry, observed a reduction in tree growth resulting from an excess of either sulfate or chloride in the nutrient solution. However, chloride reduced growth far more than sulfate at the same concentration (670 p.p.m.). High levels of chloride also resulted in leaf scorch while similar levels of sulfate did not result in leaf injury.

Hayward and Long (23) found tip-burn and mottling of peach leaves resulted from growing trees in a high chloride nutrient solution. Both chloride and sulfate reduced tree growth.

Magistad et. al. (36) reported chloride to be more toxic than sulfate, in isomotic concentration, with several vegetable crops.

Strong (54) studied the effect of calcium chloride used for dust control along Michigan highways. He observed slight to extreme leaf scorch on several shade trees during the summer months where run-off water containing calcium chloride penetrated the soil in which the trees were growing. Conifers were found more susceptible to injury than deciduous trees. Rudolfs (49) found maple, birch, chestnut, and oak (in order of increasing tolerance) susceptible to chloride injury.

The process of ion accumulation by plants has received considerable attention during the past twenty years. Overstreet and Dean (40) have summarized the accepted concents thusly:

> "The process of ion absorption by plants requires expenditure of energy. No ion accumulation occurs in the absence of respiration and other metabolic activities. When metabolic activity is inhibited, accumulation of anions and cations is likewise inhibited. The absorption process is an exchange process. Cations are absorbed in exchange for hydrogen ions and anions are absorbed in exchange for hydroxyl or bicarbonate ions which are released to the culture medium. The evidence indicates that no ion passes in or out of a healthy plant except by exchange for another ion. Ion accumulation is to a large extent selective. Due to the exchange character of the process, anions can enter the plant independently of cations and vise versa. All ions are not absorbed at the same rates. In general potassium, ammonium, rubidium, and cesium (monovalent cations) are rapidly accumulated while calcium, magnesium and barium (divalent cations) are more slowly accumulated. The anions nitrate, bromide, and chloride are usually rapidly absorbed. The anions sulfate and phosphate more slowly absorbed; and anion bicarbonate is apparently not taken up at all. In concentrations below 0.005 N, the rate of accumulation of an ion is dependent on its concentration of the culture medium."

It is obvious that the sum of anions plus cations must be balanced in the plant to maintain electrical neutrality. Lundegardh (35) proposed that the uptake of anions creates the absorption potentially for the uptake of cations in attaining this neutrality. Bear and Prince (4) established the concept of cation constantancy in alfalfa and concluded that if one ion was absorbed to a lesser extent, some other ion or ions would be absorbed to a greater extent to keep the sum of ions constant. The dissapation of formation of organic acids has been reported by Ulrich (5) to be the balancing mechanism in maintaining cation-anion equivalency.

The literature pertaining to the inter-relationship of anions and cations as related to plant growth and composition is voluminous. Specific relationships as found for a particular crop may not hold true for the same crop, and least of all for different crops, under a wide range of environmental conditions. Many instances where chloride and sulfate anions have been found to influence plant composition have been reported.

According to Leonard et. al. (33) sulfate depressed the absorption of nitrate in sweet potatoes.

Carolus (8) working with beans found that sulfate, phosphate, nitrate, and chloride did not detrimentally influence the uptake and utilization of calcium. Buchner (7), on the other hand, found chloride enhanced absorption of calcium in buckwheat and beans, especially when the ammonium form of nitrogen was present.

Parups (42) studied anion balance in Montmorency cherry. He observed that as chloride and sulfate concentrations were increased in the nutrient solution the potassium content of leaves was decreased. However, chloride exerted a far greater depressing effect than sulfate. Chloride was found to enhance calcium and magnesium absorption whereas sulfate depressed the absorption of these ions. Chloride and sulfate accumulation in leaves increased with increasing concentration of these ions in the nutrient solution.

Cooper and Gortner (11), in their work with grapefruit, found leaf potassium and calcium was reduced by high chloride while magnesium was not affected.

Harper (22), found potassium accumulation in pecan leaves was not reduced by the presence of a high chloride content in the soil.

Haas and Reed (21), working with lemons, studied the absorption of chloride from various salts and reported that a greater quantity of chloride was accumulated in leaves from potassium and calcium salts than from sodium or magnesium salts.

Gilbert et. al. (17) found that tung leaves absorbed more potassium when supplied with monovalent anions than when supplied with divalent or polyvalent anion sources. The anions studied were chloride, nitrate, sulfate, tartrate and pectate.

Overstreet et. al. (41), working with excised barley roots, found calcium absorption directly proportional to calcium chloride concentration up to 0. 200 N. Potassium absorption, however, increased with increasing potassium chloride up to 0. 08 N after which absorption dropped off markedly.

In a long term study of potassium chloride versus potassium sulfate in grape nutrition, Vinet (58) concluded, after the third year of high applications, potassium sulfate proved to be a better source of potassium than potassium chloride. The chloride associated with the high rates of application, decreased the efficiency of potassium utilization while sulfate did not.

Kenworthy (31) found grapes and peaches absorbed more potassium from soils supplied with potassium sulfate than from soils supplied with potassium chloride. The responses appeared to be related to soil type.

On the other hand, Skinner (53) found potassium chloride as good as potassium sulfate as a fertilizer for cotton.

Buchner (7) found high chloride content reduced the ratio of inorganic cations to inorganic anions in buckwheat and beans. Pierce and Appleman (43) reported a similar response with several vegetable crops. In contrast to those reports, Kretschmer et. al. (32) found that increasing the chloride or sulfate concentration of the nutrient solution did not alter the ratio of cations to anions with several of the same vegetable crops.

Cooper and Gortner (11) related the manifestation of chloride toxicity to an excess accumulation of chloride over a total cation increase.

Rathje (45) working with lower green plants, observed reduced potassium absorption as chloride, and to a lesser extent sulfate, accumulated and attributed this to the acidifying effect of chloride on plant cells.

The dissipation or formation of malic acid, in the presence of excessive anions or cations respectively, was thought to be a major factor in total anion-cation balance in plants according to Ulrich (57).

Jacobson (26) and Jacobson and Ordin (27) reported that unequal absorption of anions and cations by barley roots was reflected by changes in organic acid content of roots. Greatest changes were observed in malic acid content (the predominant organic acid present). Excessive cation accumulation derived from a 0. 005 N potassium bicarbonate solution, increased malic acid content. Excessive anion accumulation, derived from a 0. 005 N calcium bromide solution, decreased malic acid content.

Anderson et. al. (1) advised against the use of potassium chloride as a fertilizer for tobacco. Chloride, being very mobile in the soil and easily accumulated by tobacco, exerted a deleterious effect on burning quality of tobacco. Sulfate, nitrate and carbonate of potash, being less easily absorbed by tobacco, exerted a far less adverse effect on burning quality and were therefore deemed better sources of potassium. Burning quality of tobacco has been related to high potassium and high organic acid (especially bicarbonate, malic and citric acid) content of the leaf.

Garner et. al. (15) found a high chloride concentration associated with dissipation of malic acid content in tobacco leaves. Since organic acids are the major component of the buffer mechanism of plant cells conditions affecting their dissipation could have direct bearing on pH control within the cell and the associated protoplasmic activity.

Dunn and Nylund (12) studied the influence of fertilizers on specific gravity of potatoes. In general, high specific gravity was associated with high starch content and high cooking quality in potatoes. They concluded that potash fertilizers containing chlorides caused a marked reduction in specific gravity, and the reduction was related directly to application. Sulfate of potash did not reduce specific gravity of the potatoes, indicating that the chloride anion was responsible for increasing the water content of potatoes.

Baslavskaya (3) reported that potato leaves from plants receiving chloride contained more starch than leaves from plants not receiving chloride.

Gauch and Eaton (16) found barley plants had higher starch and sugar content when grown in saline sand culture. This suggested that the accumulated salts interfered with cellular activities associated with carbohydrate utilization.

Riesenauer and Colwell (48) found chloride absorption by tobacco plants directly related to the hydrogen ion concentration of the culture medium. Calcium, nitrogen and sulfate reduced chloride absorption.

Nielson and Overstreet (38), working with barley roots, reported a decrease in potassium absorption was directly related to the hydrogen ion concentration of the culture medium. Calcium decreased the inhibiting effect of hydrogen ion on potassium uptake.

Overstreet, Jacobson and Handley (41) reported that calcium stimulated potassium absorption in barley roots in high potassium solutions but inhibited potassium absorption in low potassium solutions.

As early as 1902 Wheeler and Hartwell (61) recognized the toxic effect of chloride to certain plants and reported that liming the soil could counteract this toxicity. Piland and Willis (44) reported similar beneficial results of liming to counteract chloride toxicity in certain plants.

Buchner (7) working with buckwheat and beans found chloride absorption was favored in the presence of the ammonium form of nitrogen as compared to the nitrate form.

MATERIALS AND METHODS

Specific effects of chloride concentrations, sulfate concentration and chloride-sulfate combinations on the growth and leaf composition of cherry, apple, peach and grape were studied by means of nutrient solution methods. To single out specific effects of chloride, sulfate and chloride-sulfate combinations three concentrations of chloride (0, 355, 655 p.p.m.) and sulfate (192, 384, 624 p.p.m.) were employed in a 3 x 3 factorial design Cochran and Cox (10).

To obtain the nine nutrient solutions containing the concentrations of chloride and sulfate desired, Hoagland's (24) nutrient solution was used and the metallic cation content kept constant.[1] This was accomplished by using different amounts of various C.P. grade chemicals dissolved in distilled water and varying the nitrogen source between ammonium and nitrate nitrogen (Appendix Tables 1 and 2). Conductivity readings were taken on each solution with a Solu-bridge (model DR-15) and the pH of the solutions was measured with a Beckman pH meter (model H2).

The following kinds of fruit plants were used: one-year-old Montmorency cherry trees (Prunus cerasus budded on Prunus Mahaleb; one-year-old Delicious apple trees (Pyrus malus budded on Pyrus malus); one-year-old Elberta peach trees (Prunus persica budded on Prunus persica var. Lovell);

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[1] To maintain Hoagland's metallic cation content it was necessary to reduce the concentration of chloride and sulfate to 497 and 574 p.p.m. respectively in the treatment containing the high levels of each.

and one-year-old own-rooted Concord grape (*Vitus labrusca*) cuttings.

Twenty seven plants of each kind of fruit were selected. The trees were pruned uniformly and divided in three size groups according to weight after pruning. Trees with approximately the same weight were put in the same replicate, thus making three replicates for each treatment. The grape plants were selected to provide the same weight after pruning to two buds. Green and dry weights of representative plant parts were obtained from a separate lot of plants and the per cent dry matter calculated. This value was used to obtain initial dry weight of the experimental plants.

The trees and rooted cuttings were planted in 12-inch clay pots in the greenhouse on January 28, 1956. The pots were previously painted with an asphaltum compound to prohibit root contact with the surface of the clay pots. Coarse quartz sand was used as the growing media.

The pots were numbered and arranged in three randomized blocks for each crop on four greenhouse benches. Application of nutrient solutions commenced one week after planting. Each plant received one quart of solution every third day during the first month, and one quart every second day during the second month. Later as growth demanded, daily application of solution was necessary. The plants received bi-weekly and later tri-weekly flushing with distilled water to avoid excessive salt accumulation in the pots. At the beginning of the third month, and extending for two weeks, nutrient solution was withheld from plants receiving the high chloride treatment. Distilled water was substituted in an effort to bring the plants back into growth. During this two week period of distilled water application, growth was renewed and the regular schedule of nutrient application was re-established.

The plants were harvested on May 21, 22, 23 and 25. Linear growth of shoots, dry weight of leaves, shoots, fibrous roots, large roots and trunk was obtained and increase in total dry weight was calculated. Dry weight of fibrous roots was obtained by passing dried, crumbled roots through two standard seives (sizes U. S. 20-840 microns opening and U. S. 45-350 microns opening). Those roots passing through the smaller seive were weighed as fibrous roots.

Leaves from each tree and stems[1] from grape were analyzed in the Agricultural Chemistry Department Laboratory. Nitrogen was determined by the Kjeldahl method, potassium by flame photometer, phosphorus, calcium, magnesium, iron, manganese, boron, copper and zinc were determined spectrographically. Chloride was determined by a modified method of Samson (50). Sulfate was determined gravemetrically in accordance with the A. O. A. C. method (39).

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[1] Stem analysis rather than petiold analysis was necessary due to insufficient petioles from certain treatments. However, petioles were used for chloride and sulfate determination.

RESULTS

Growth

Data pertaining to increase in total dry weight, dry weight of shoots, leaves fibrous roots, and linear growth of shoots for the four crops can be found in Appendix Tables 3, 4, 5 and 6.

General Observations

Within one month after the application of nutrient solution was initiated, visual differences in linear growth of all crops due to differential sulfate and chloride treatment were observed. Linear growth of all crops was depressed as the chloride concentration in the nutrient solution increased. Of the four crops, apple appeared most sensitive and peach least sensitive to the high (665 p. p. m.) chloride concentration. No visual differences in linear growth due to sulfate concentration were observed for any crop until the end of the second month. However, at the end of the second month, linear growth of cherry had been depressed slightly from both medium and high sulfate levels. No response to sulfate concentration was observed for apple and grape. Peach trees seemed to benefit from a medium (384 p. p. m.) sulfate supply. The leaves took on a dark green cast and the shoots appeared more vigorous than on trees receiving less sulfate (192 p. p. m.). Visual linear growth differences due to sulfate and chloride in combination were expressed mainly as a chloride effect for all crops. Differences in growth of all crops due to treatment became more pronounced with time. Figures 1 and 2 show the response of

apple and peach trees to the treatments. The response of cherry and grape plants were similar to that shown for apple and peach.

Leaf symptoms developed on peach trees receiving high chloride solutions by the end of the second month. The symptom appeared first on trees receiving high chloride (665 p.p.m.) and low sulfate (192 p.p.m.). Similar, though far less intense, symptoms appeared later on trees receiving high chloride and medium sulfate (384 p.p.m.). The terminal leaves were afflicted first. As the new leaves unfolded a chlorosis developed beginning at the base and extending up the margin of the leaves. This chlorosis soon gave way to a marginal necrotic scorch as the leaves enlarged. Leaves so afflicted abscissed readily (Figure 2 - upper right hand corner). The general leaf color was pale green on trees receiving high chloride, compared to the dark green leaves on trees receiving no chloride. Slender stems and small leaves were also a result of high chloride treatment.

Leaf symptoms also developed on peach trees receiving the medium chloride (315 p.p.m.) - high sulfate (624 p.p.m.) solution. The terminal leaves were most severely damaged. Interveinal chlorosis started at the base and extended to the tip of terminal leaves. The interveinal chlorosis gave way to a necrotic "shot-hole" effect accompanied by considerable crinkling near the midrib. Similar, though less intense, symptoms resulted from the medium chloride - medium sulfate solution.

Grapes receiving medium chloride - high sulfate solution developed leaf symptoms during the fourth month as shown in Figure 3. Leaves along the

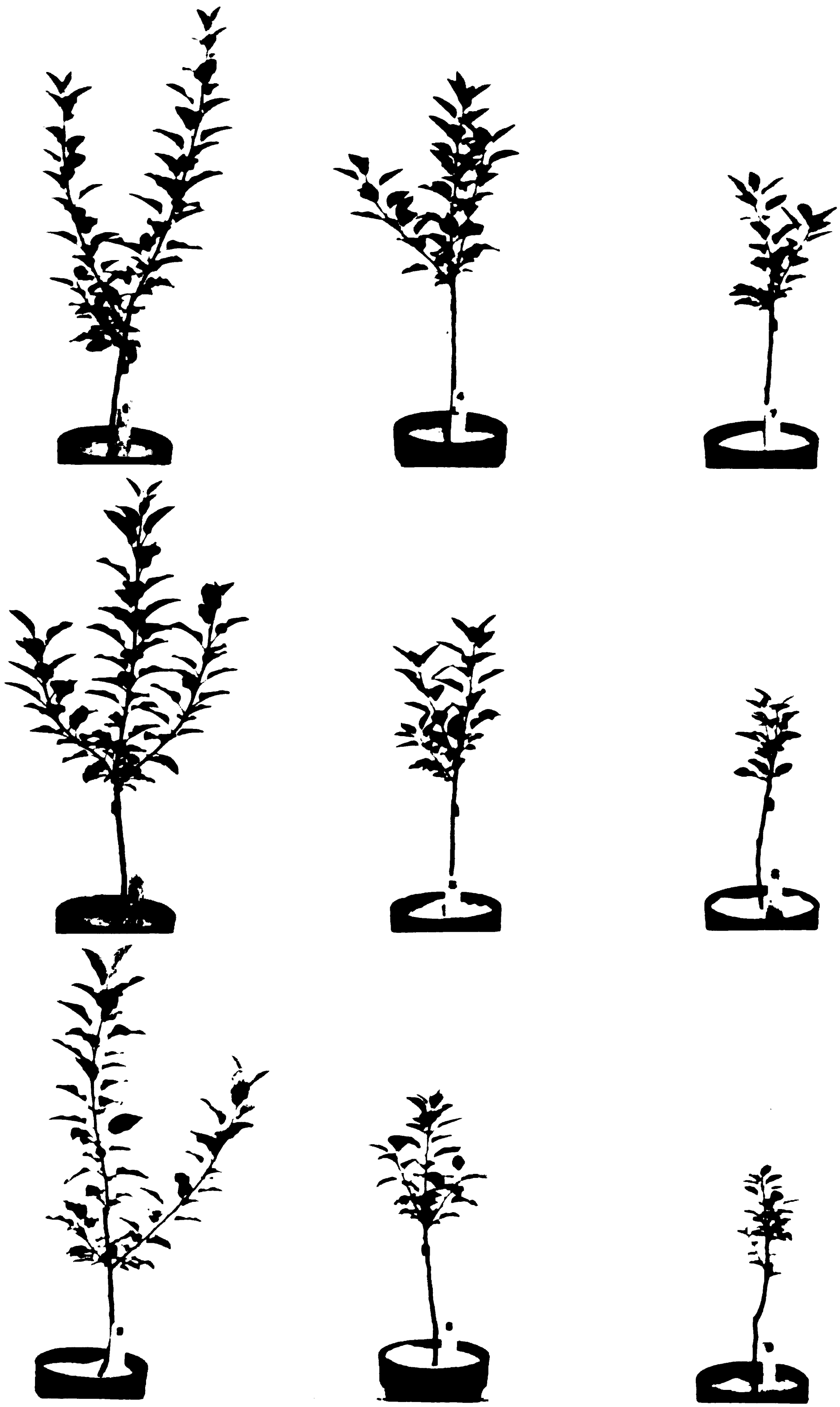


Figure 1.

Influence of chloride and sulfate supply on the growth of Delicious apple trees.

From left to right --- increasing chloride supply from 0-315-665 p. p. m.

From top to bottom --- increasing sulfate supply from 192-384-624 p. p. m.

Figure 2.

Influence of chloride and sulfate supply on growth of Elberta peach trees.

From left to right --- increasing chloride supply from 0-315-665 p. p. m.

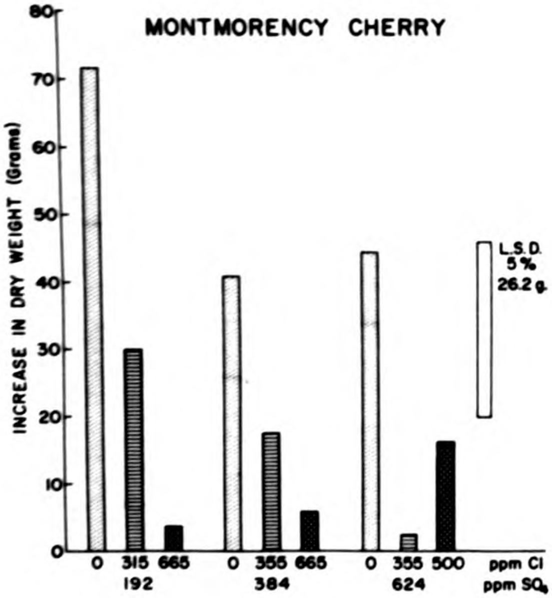
From top to bottom --- increasing sulfate supply from 192-384-624 p. p. m.

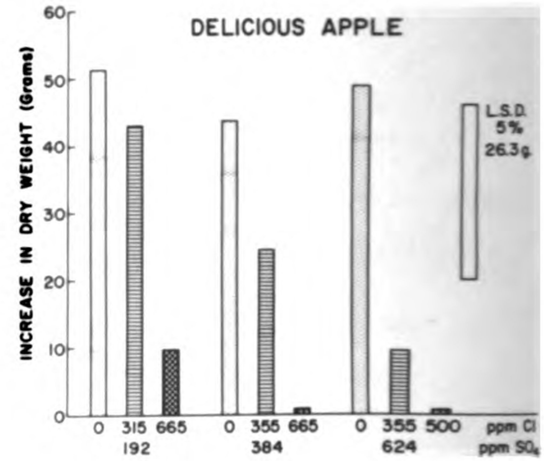
Figure 3.

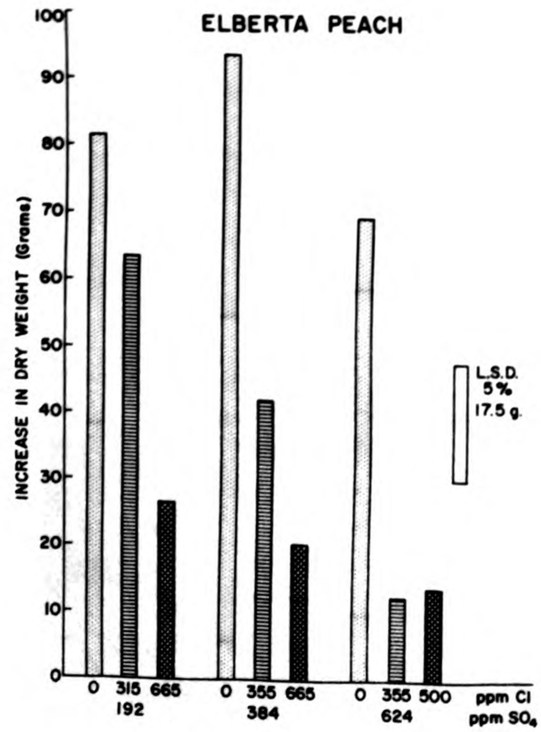
Influence of medium chloride (355 p.p.m.) and high sulfate (624 p.p.m.) on Concord grape.

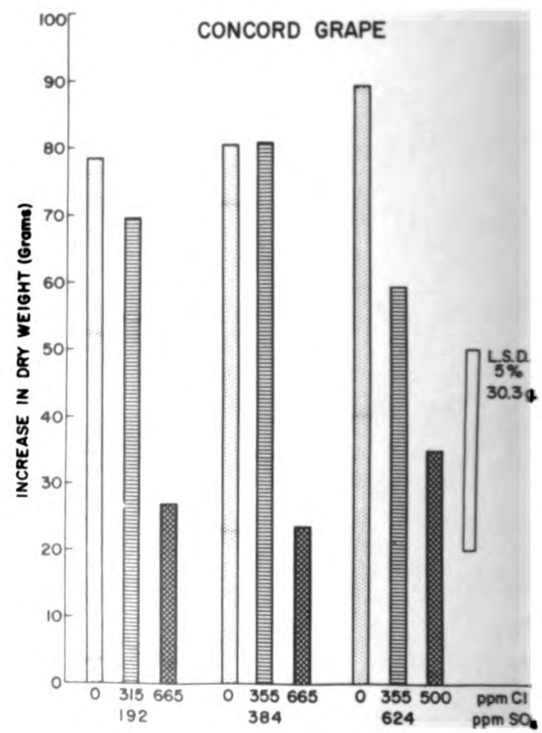
middle and extending upward including those on the terminal portion of the shoot showed interveinal chlorosis. The chlorosis soon developed into necrotic blotches covering a considerable area of the leaf. The medium chloride - medium sulfate treatment gave similar, though less intense, symptoms.

Leaf symptoms did not develop on cherry or apple from chloride or sulfate treatment. However, the leaves of both crops were much smaller on trees supplied with chloride than on trees not receiving chloride.


MONTMORENCY CHERRY
INCREASE IN DRY WEIGHT (Grams)
80
70
60
50
40
30
20
10
0
L.S.D.
5%
26.2 g.
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


DELICIOUS APPLE
INCREASE IN DRY WEIGHT (Grams)
60
50
40
30
20
10
0
L.S.D.
5%
26.3 g.
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


ELBERTA PEACH
INCREASE IN DRY WEIGHT (Grams)
100
90
80
70
60
50
40
30
20
10
0
L.S.D.
5%
17.5 g.
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


CONCORD GRAPE
INCREASE IN DRY WEIGHT (Grams)
100
90
80
70
60
50
40
30
20
10
0
L.S.D.
5%
30.3 g.
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

Increase in total dry weight. (see figure opposite)

Increasing the chloride concentration from 0 to 665 p. p. m. with 192 p. p. m. of sulfate reduced dry matter accumulation in cherry trees. The 384 and 624 p. p. m. sulfate levels accentuated the depressing effect of increased chloride concentration. Increasing the sulfate supply from 192 to 384 p. p. m. to trees not receiving chloride reduced dry matter accumulation but further increase in sulfate supply did not.

As the chloride concentration was increased from 0 to 315 p. p. m. with 192 p. p. m. sulfate dry matter accumulation in apple trees was reduced slightly whereas increasing chloride to 665 p. p. m. drastically reduced it. The 384 and 624 p. p. m. sulfate concentrations accentuated the depressing effect of increasing chloride supply. Increasing the sulfate supply to trees not receiving chloride did not influence dry matter accumulation but when chloride was included it was depressed.

Increasing the chloride supply to peach trees receiving 192 p. p. m. sulfate reduced dry matter accumulation with each increment in chloride. The 384 and 624 p. p. m. sulfate levels accentuated the depressing effect of chloride. Supplying 384 p. p. m. of sulfate without chloride enhanced dry matter accumulation in peach trees while further increase in sulfate supply to 624 p. p. m. reduced it.

Grape plants tolerated 315 p. p. m. of chloride when supplied with 192 or 384 p. p. m. of sulfate but the 665 p. p. m. chloride concentration drastically depressed dry matter accumulation regardless of the sulfate supply. A stepwise reduction in increase on total dry weight occurred as the chloride supply was increased with-

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in the 624 p. p. m. sulfate concentration. Increasing the sulfate supply from 192 to 624 p. p. m., regardless of chloride supply, did not effect dry matter accumulation in grape plants.

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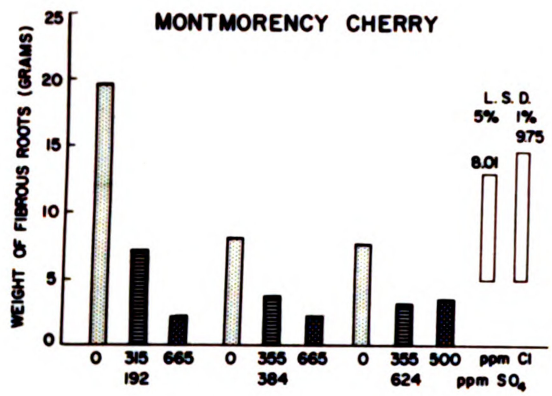
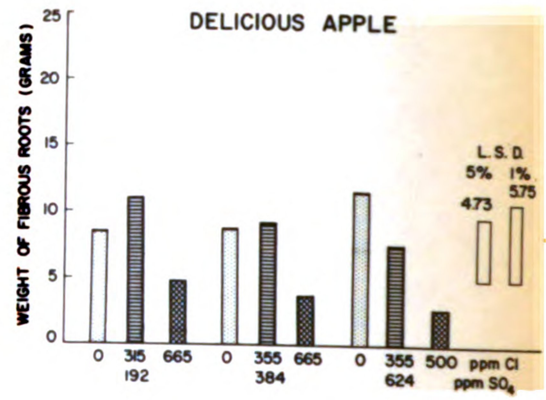
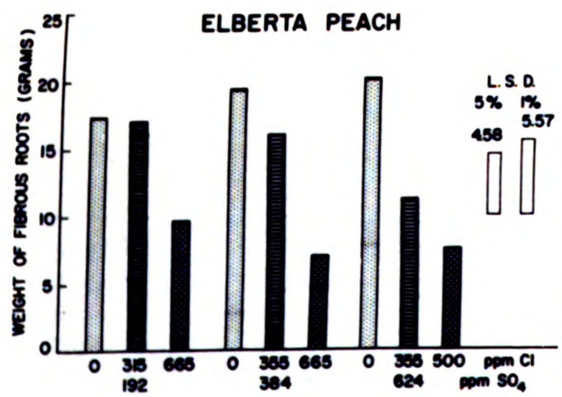
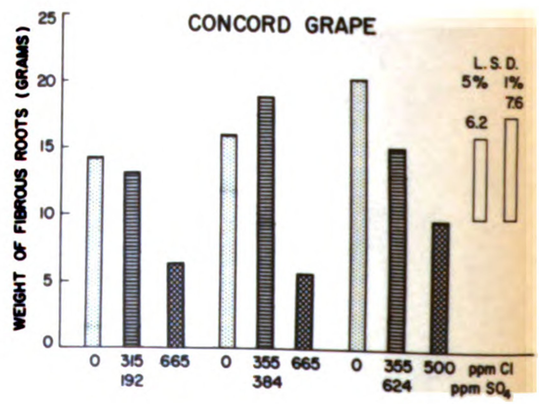

MONTMORENCY CHERRY
WEIGHT OF FIBROUS ROOTS (GRAMS)
25
20
15
10
5
0
L. S. D.
5% 1%
8.01 9.75
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


DELICIOUS APPLE
WEIGHT OF FIBROUS ROOTS (GRAMS)
25
20
15
10
5
0
L. S. D.
5% 1%
4.73 5.75
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


ELBERTA PEACH
WEIGHT OF FIBROUS ROOTS (GRAMS)
25
20
15
10
5
0
L. S. D.
5% 1%
4.58 5.57
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


CONCORD GRAPE
WEIGHT OF FIBROUS ROOTS (GRAMS)
25
20
15
10
5
0
L. S. D.
5% 1%
6.2 7.6
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

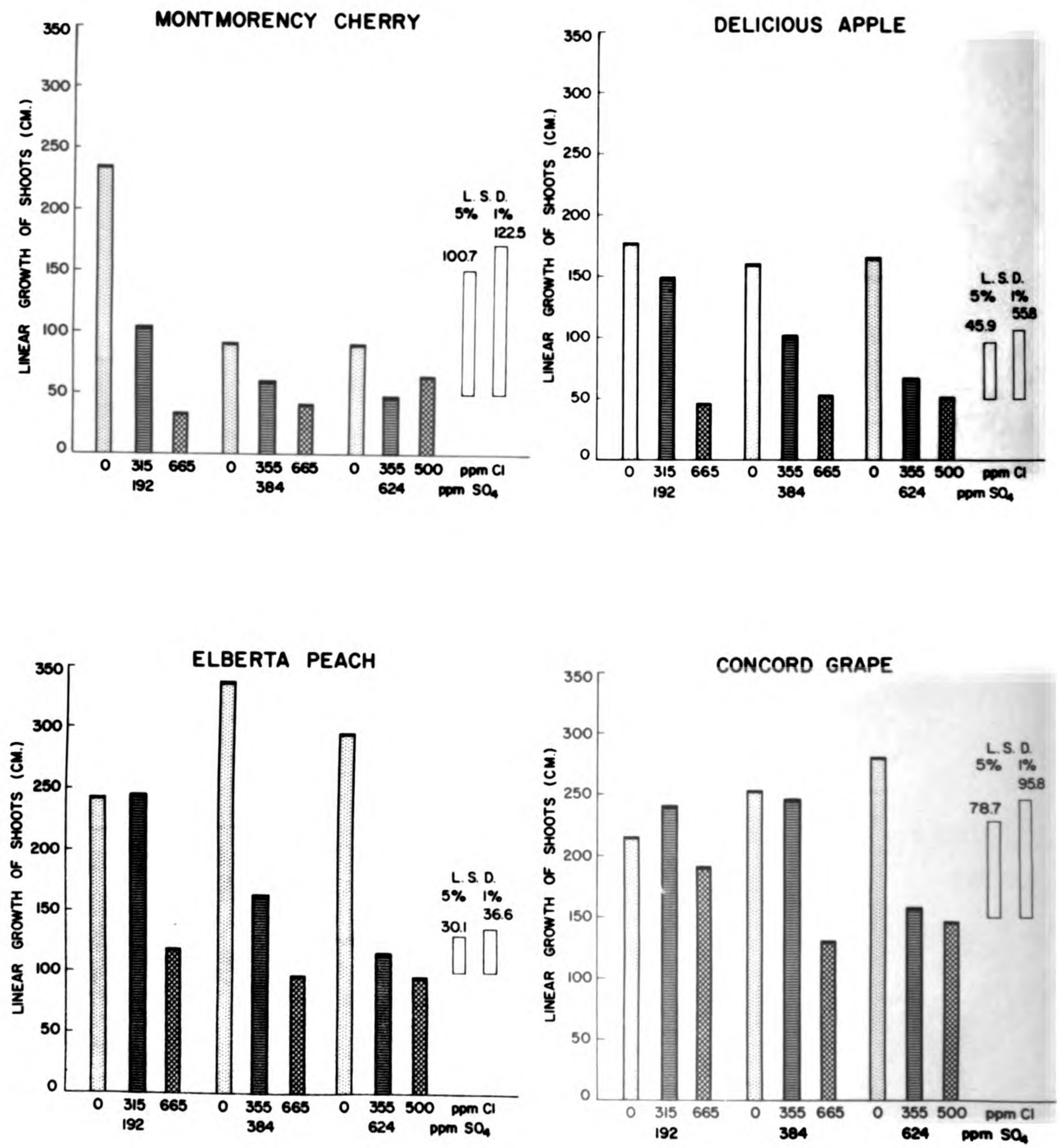
Weight of fibrous roots (see figure opposite)

Increasing the chloride concentration from 0 to 665 p. p. m. with 192 p. p. m. sulfate reduced the dry weight of fibrous roots from cherry trees. The higher sulfate levels accentuated the depressing effect of the 355 p. p. m. chloride concentration. Increasing the sulfate supply from 192 to 384 p. p. m. in the absence of chloride reduced fibrous root growth while further increase in sulfate supply did not induce additional growth depression.

As chloride was increased from 0 to 315 or 355 p. p. m. with 192 or 384 p. p. m. of sulfate root growth of apple trees was not affected but when supplied with 624 p. p. m. of sulfate fibrous root growth was reduced. Increasing the chloride supply to 665 p. p. m. reduced root growth within all sulfate concentrations. The depressing effect of 355 and 665 p. p. m. chloride was accentuated as the sulfate supply increased. Increasing the sulfate supply from 192 to 624 p. p. m. to trees not receiving chloride did not affect fibrous root growth of apple trees.

The 315 or 355 p. p. m. chloride concentrations did not affect root growth of peach trees receiving 192 or 384 p. p. m. of sulfate. The 665 p. p. m. chloride level drastically reduced root growth with all sulfate concentrations. At the 624 p. p. m. sulfate level the depressing effect of 355 p. p. m. of chloride became more pronounced.

Increasing the chloride concentration from 0 to 665 or 500 p. p. m. within any sulfate level reduced root growth in grape plants. Increasing the sulfate supply enhanced root growth when supplied without chloride. At the 355 and 665 p. p. m. chloride concentrations increasing the sulfate supply did not markedly affect growth of grape roots.


MONTMORENCY CHERRY
DELICIOUS APPLE
ELBERTA PEACH
CONCORD GRAPE
LINEAR GROWTH OF SHOOTS (CM.)
0
50
100
150
200
250
300
350
L. S. D.
5%
1%
100.7
122.5
45.9
55.8
30.1
36.6
78.7
95.8
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4

Linear growth of shoots (see figure opposite)

Increasing the chloride concentration from 0 to 665 p.p.m. with the 192 p.p.m. sulfate level reduced shoot growth of cherry trees. Increasing the chloride level within the 384 and 624 p.p.m. sulfate concentration tended to accentuate the depressing effect of the 355 p.p.m. chloride concentration. Linear growth of cherry shoots was reduced as much by the 384 p.p.m. sulfate as the 624 p.p.m. sulfate level or the 315 p.p.m. chloride concentration.

As the chloride supply to apple trees receiving 192 p.p.m. of sulfate was increased from 0 to 665 p.p.m. a reduction in shoot growth resulted. Increasing the chloride supply depressed linear growth of apple shoots more as sulfate was increased in the nutrient solution. Increasing the sulfate supply in the absence of chloride or with 665 p.p.m. of chloride did not influence growth of shoots. However, increasing the sulfate supply to trees receiving 355 p.p.m. of chloride reduced growth.

The 315 p.p.m. chloride concentration did not influence linear growth of peach shoots when supplied with 192 p.p.m. of sulfate while the 665 p.p.m. chloride concentration markedly reduced growth. As the chloride supply was increased with the 384 or 624 p.p.m. sulfate levels the growth depression due to chloride became more pronounced. Increasing the sulfate supply from 192 to 624 p.p.m. enhanced growth of peach shoots on trees not receiving chloride, depressed growth when supplied with 355 p.p.m. of chloride, and did not significantly affect growth when supplied with 665 p.p.m. of chloride.

Linear growth of grape shoots was not appreciably influenced by increasing the chloride supply from 0 to 315 or 355 p.p.m. within the 192 or 384 p.p.m.

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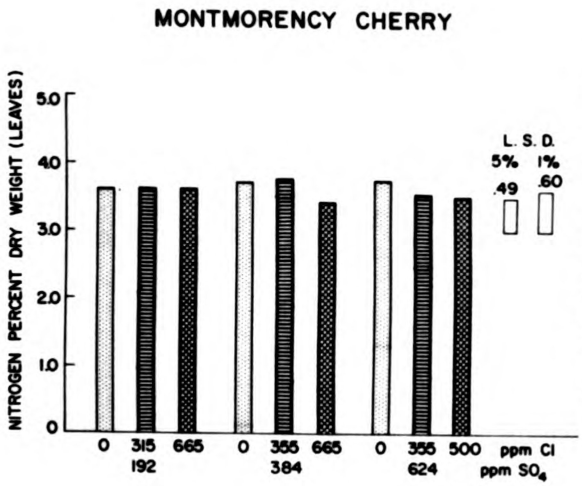
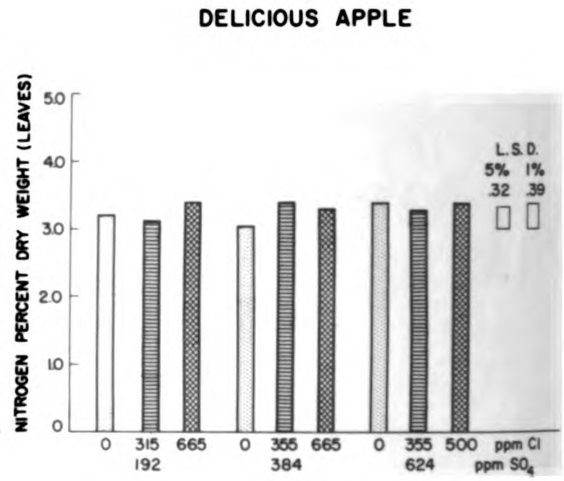
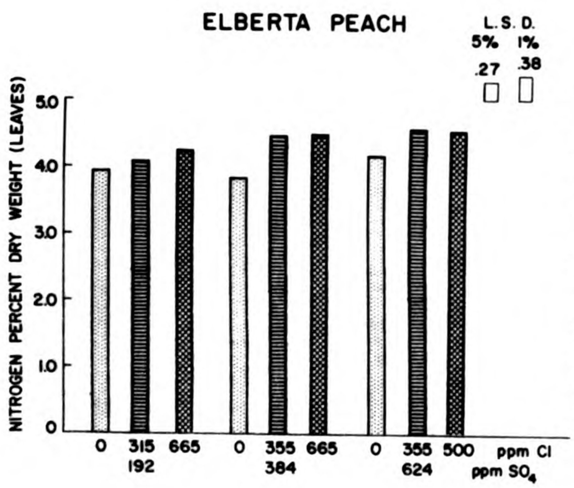
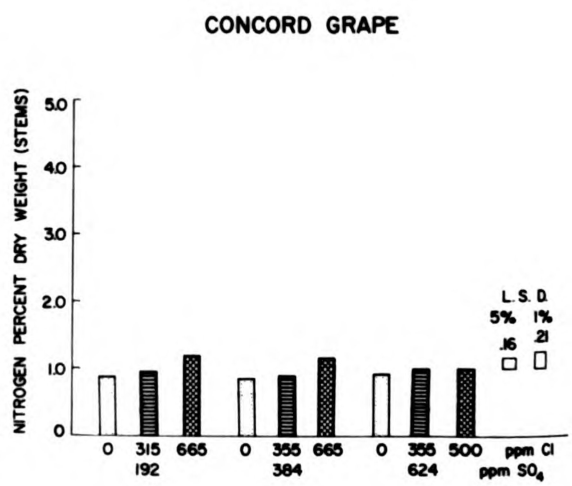
sulfate concentrations but drastically reduced growth when supplied with 624 p.p.m. of sulfate. The 665 p.p.m. chloride concentration did not greatly reduce growth unless used with 384 or 624 p.p.m. of sulfate. Sulfate when supplied without chloride tended to increase growth but when chloride was added sulfate accentuated the depressing effect of chloride.


MONTMORENCY CHERRY
NITROGEN PERCENT DRY WEIGHT (LEAVES)
L. S. D.
5% 1%
.49 .60
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


DELICIOUS APPLE
NITROGEN PERCENT DRY WEIGHT (LEAVES)
L. S. D.
5% 1%
.32 .39
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


ELBERTA PEACH
L. S. D.
5% 1%
.27 .38
NITROGEN PERCENT DRY WEIGHT (LEAVES)
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


CONCORD GRAPE
NITROGEN PERCENT DRY WEIGHT (STEMS)
L. S. D.
5% 1%
.16 .21
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

Leaf Composition

Data pertaining to the chemical composition of leaf tissue for the four fruit crops can be found in Appendix Tables 7, 8, 9 and 10.

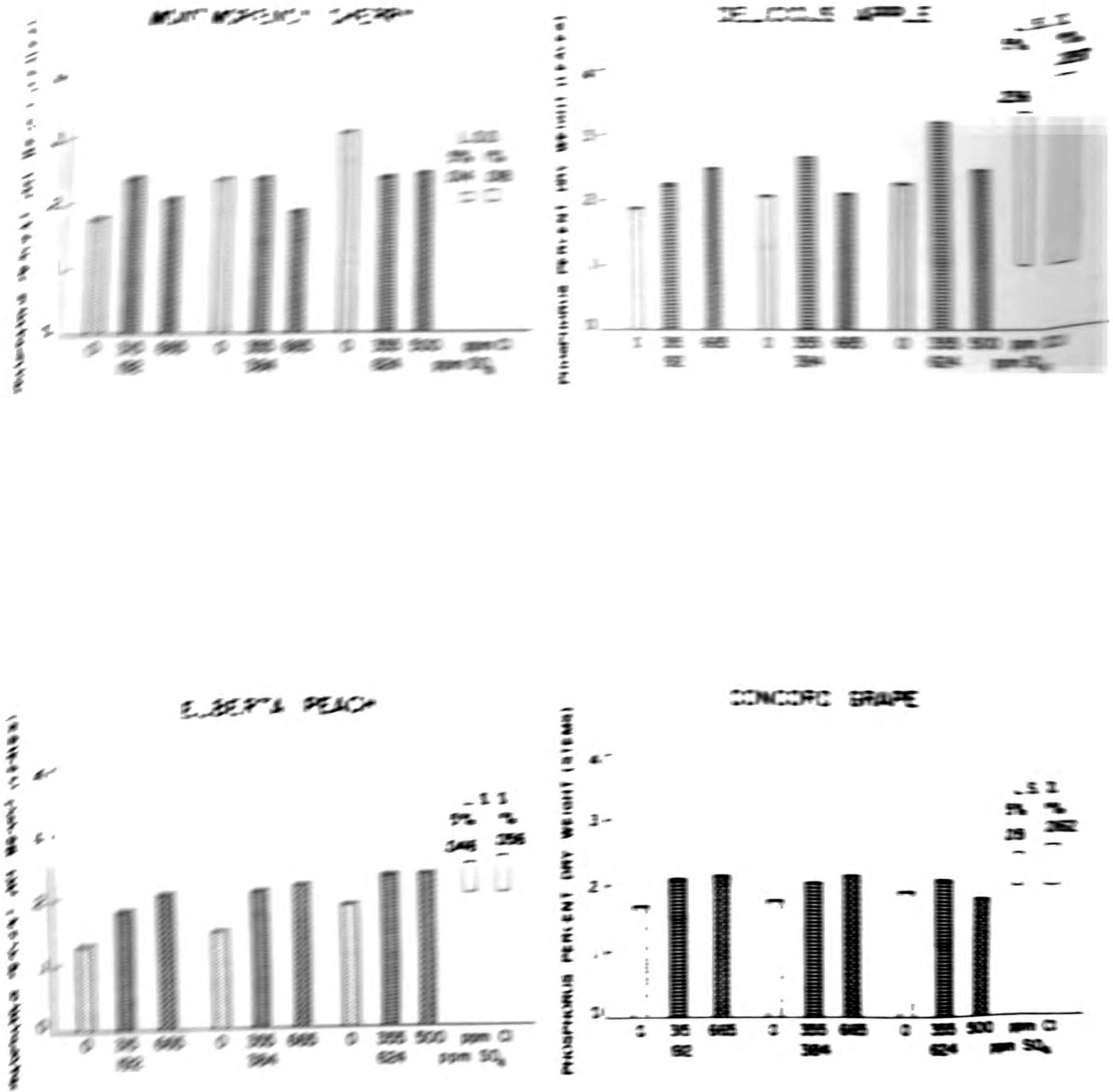
Nitrogen (see figure opposite)

Increasing the supply of chloride in the nutrient solution from 0 to 665 p.p.m. had no effect on nitrogen content in cherry leaves from trees supplied with 192 p.p.m. of sulfate. Though the differences were not significant increasing the chloride concentration within the 384 p.p.m. sulfate and more so within the 624 p.p.m. sulfate levels tended to reduce nitrogen accumulation. Nitrogen content in cherry leaves was not markedly influenced by increasing the sulfate supply regardless of the chloride concentration.

Apple leaves did not vary significantly in nitrogen content as the chloride supply was increased from 0 to 665 p.p.m. regardless of the sulfate concentration. Leaves from trees supplied with increasing amounts of sulfate and no chloride had nearly the same nitrogen content.

Increasing the chloride concentration from 0 to 665 p.p.m. within the 192 p.p.m. sulfate level increased the nitrogen content in peach leaves. As chloride levels were increased with higher sulfate levels there was a greater increase in nitrogen content than resulted from increasing the chloride supply within the 192 p.p.m. sulfate concentration. All sulfate levels in the absence of chloride gave nearly the same nitrogen values.

Grape stems had a higher nitrogen content when the chloride concentration was increased within the 192 and 384 p.p.m. sulfate levels but not within the 624 p.p.m. sulfate concentration. Increasing the sulfate supply in the chloride had no effect on nitrogen content in grape stems.


ELBERTA PEACH
CONCORD GRAPE
PHOSPHORUS PERCENT DRY WEIGHT
ppm Cl
ppm SO4

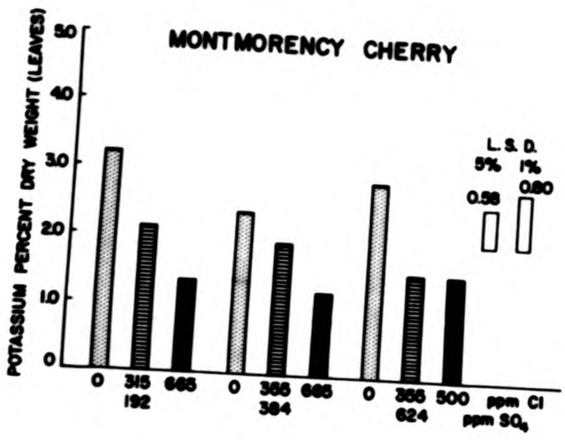
Phosphorus (see figure opposite)

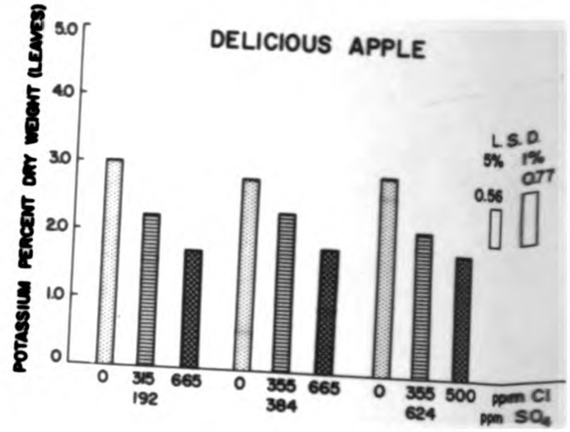
Phosphorus content in cherry leaves increased then decreased slightly as the chloride level in the nutrient solution was increased from 0 to 665 p.p.m. within the 192 p.p.m. sulfate concentration. As the chloride concentration was increased from 0 to 665 p.p.m. within the 384 and 624 p.p.m. sulfate levels phosphorus content decreased. Cherry trees receiving increasing sulfate levels in the absence of chloride increased with each increment increase in sulfate supply but not when chloride was included in the nutrient solution.

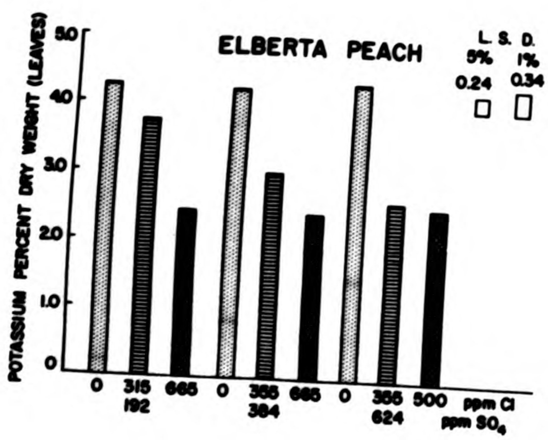
Apple leaves showed no significant differences in phosphorus content but tended to have more phosphorus in their leaves as the chloride supply was increased from 0 to 665 p.p.m. within the 192 p.p.m. sulfate level. Increasing the chloride supply from 0 to 355 p.p.m. within the 384 and 624 p.p.m. sulfate levels tended to increase phosphorus in apple leaves while the 665 or 500 p.p.m. chloride concentrations tended to reduce it. The sulfate supply did not significantly affect the phosphorus content.

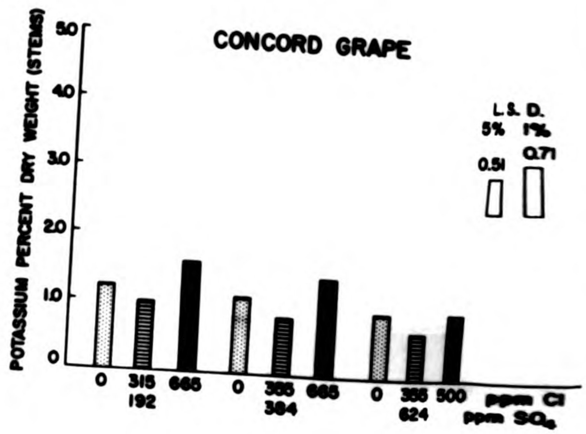
Peach leaves increased in phosphorus content as the supply of chloride increased within all sulfate concentrations. Increasing the sulfate supply increased phosphorus accumulation in peach leaves at the 0 and 355 p.p.m. chloride concentration but not at the 665 p.p.m. chloride concentration.

Grape stems tended to contain more phosphorus as the chloride supply was increased from 0 to 665 p.p.m. within the 192 and 384 p.p.m. sulfate levels but not at the 624 p.p.m. sulfate concentration. Sulfate supply did not markedly influence phosphorus content.


MONTMORENCY CHERRY
POTASSIUM PERCENT DRY WEIGHT (LEAVES)
L. S. D.
5% 1%
0.58 0.80
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4


DELICIOUS APPLE
POTASSIUM PERCENT DRY WEIGHT (LEAVES)
L. S. D.
5% 1%
0.56 0.77
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4


ELBERTA PEACH
POTASSIUM PERCENT DRY WEIGHT (LEAVES)
L. S. D.
5% 1%
0.24 0.34
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4


CONCORD GRAPE
POTASSIUM PERCENT DRY WEIGHT (STEMS)
L. S. D.
5% 1%
0.51 0.71
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4

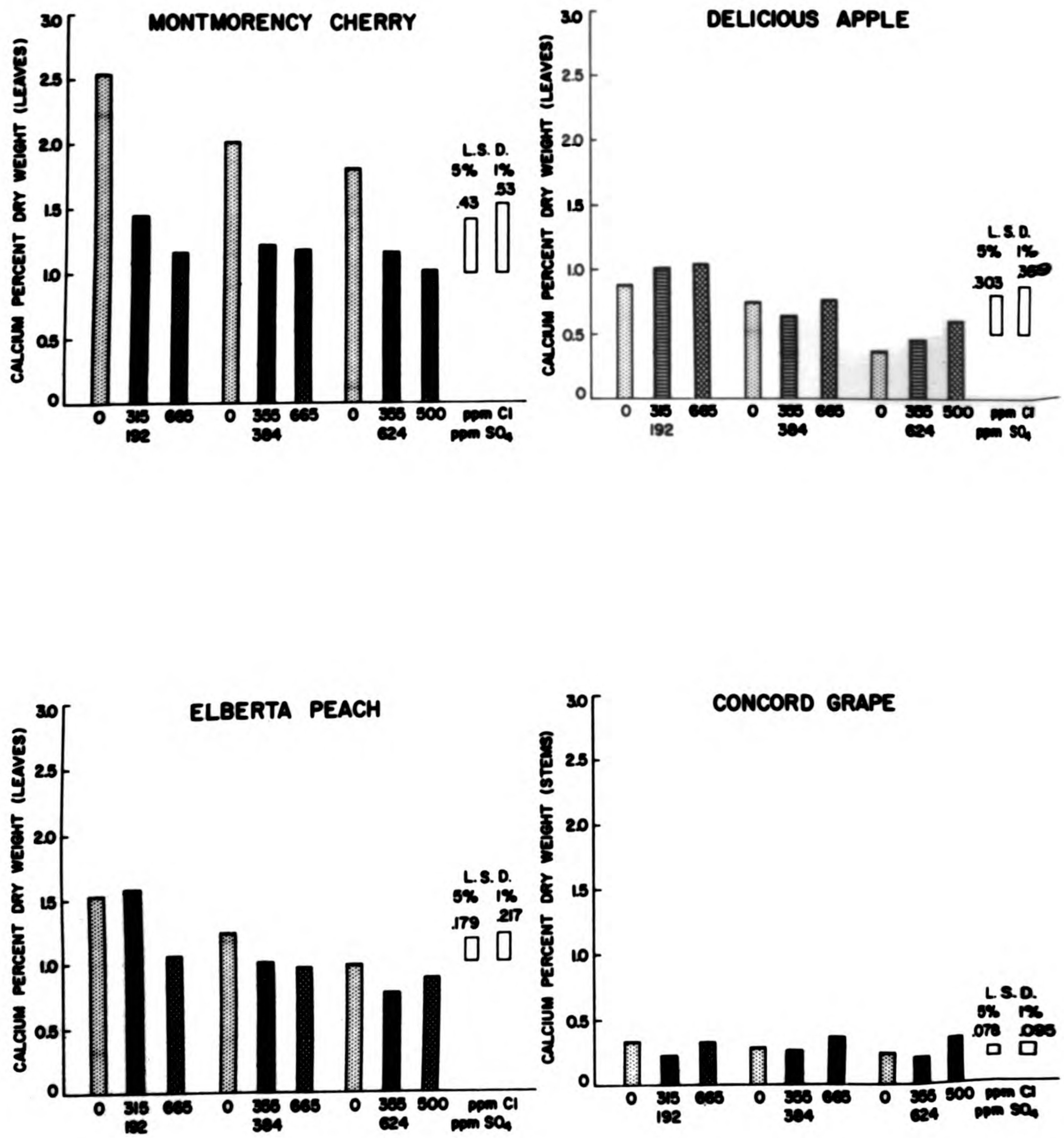
Potassium (see figure opposite)

Cherry leaves decreased in potassium content as the chloride concentration was increased from 0 to 665 p. p. m. within all sulfate levels. The 355 p. p. m. chloride level exerted a greater depressing effect on potassium accumulation as the sulfate supply was increased. Increasing the sulfate supply in the absence of chloride or with 665 p. p. m. chloride did not markedly change the potassium content while increasing the sulfate supply with 355 p. p. m. of chloride reduced it.

Apple leaves contained less potassium as the chloride supply was increased from 0 to 665 p. p. m. regardless of the sulfate concentration in the substrate. Increasing the supply of sulfate exerted no influence on potassium accumulation regardless of the chloride concentration.

Peach leaves decreased in potassium as the chloride supply was increased from 0 to 665 p. p. m. within all sulfate levels. The depressing effect of 355 p. p. m. of chloride was accentuated as the sulfate supply was increased. Increasing the sulfate supply in the absence of, or with 665 p. p. m. of chloride did not effect the potassium content in peach leaves.

Grape stems decreased slightly then increased in potassium content as the chloride supply was increased from 0 to 665 p. p. m. within all sulfate levels. At the higher sulfate levels these differences were less pronounced. In the absence of chloride, increasing the sulfate supply depressed potassium accumulation. When chloride was added to the nutrient solution increasing the sulfate supply accentuated the depressing effect of chloride on potassium accumulation.


MONTMORENCY CHERRY
CALCIUM PERCENT DRY WEIGHT (LEAVES)
L.S.D.
5% 1%
.43 .53
ppm Cl
ppm SO4
DELICIOUS APPLE
CALCIUM PERCENT DRY WEIGHT (LEAVES)
L.S.D.
5% 1%
.303
ELBERTA PEACH
CALCIUM PERCENT DRY WEIGHT (LEAVES)
L.S.D.
5% 1%
.179 .217
CONCORD GRAPE
CALCIUM PERCENT DRY WEIGHT (STEMS)
L.S.D.
5% 1%
.078
0 315 665 0 355 665 0 355 500
192 384 624

Calcium (see figure opposite)

Cherry leaves decreased in calcium content as the chloride supply was increased from 0 to 665 p. p. m. within all sulfate levels. Increasing the sulfate supply in the absence of chloride decreased the calcium content but not as severely as did the medium or high chloride levels when supplied with any sulfate concentration.

The calcium content in apple leaves tended to increase as the chloride supply was increased from 0 to 665 p. p. m. within the 192 and 624 p. p. m. sulfate concentrations though the differences were not significant. Increasing the sulfate concentration from 192 to 624 p. p. m. in the absence of chloride reduced the calcium content in apple leaves. The depressing effect of sulfate on calcium accumulation was exerted regardless of the chloride concentration.

The calcium content in peach leaves was reduced as the chloride supply was increased from 315 p. p. m. to 665 p. p. m. within the 192 p. p. m. sulfate concentration. At the 384 or 624 p. p. m. sulfate levels increasing the chloride supply from 0 to 355 reduced calcium accumulation in peach leaves. As the sulfate supply was increased from 192 to 624 p. p. m. concurrently with 0 or 355 p. p. m. of chloride the calcium content was markedly reduced. The lowest calcium value was observed at the 355 p. p. m. chloride - 624 p. p. m. sulfate concentrations.

Grape stems decreased then increased in calcium content as the chloride supply was increased from 0 to 665 p. p. m. regardless of the sulfate supply. Increasing the sulfate supply with 0 or 255 p. p. m. of chloride reduced the calcium content. The greatest reduction in calcium content in grape stems occurred when 355 p. p. m. of chloride and 624 p. p. m. of sulfate were combined.

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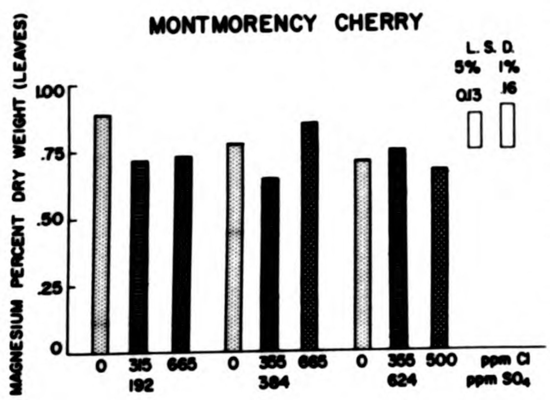
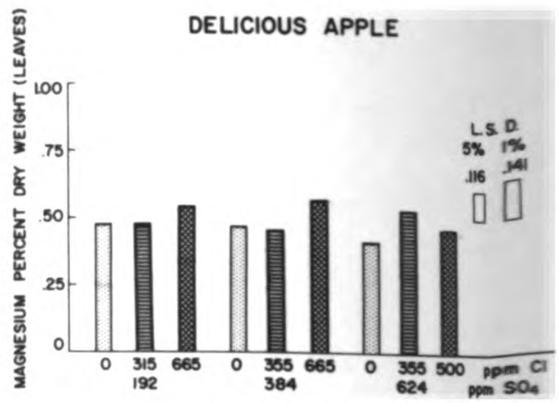
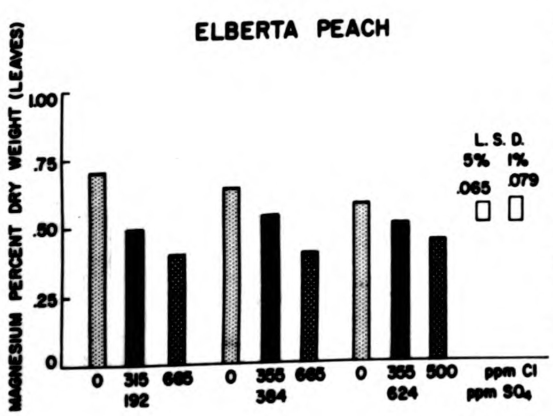
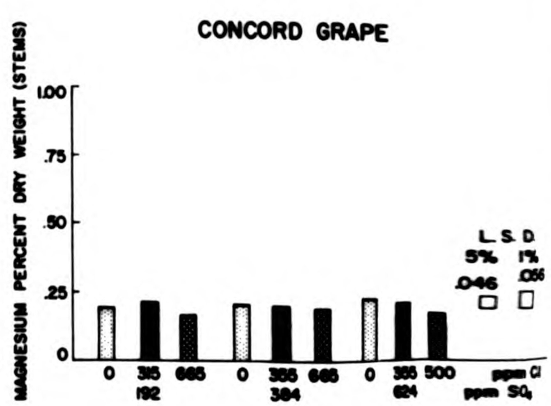

MONTMORENCY CHERRY
MAGNESIUM PERCENT DRY WEIGHT (LEAVES)
1.00
.75
.50
.25
0
L. S. D.
5% 1%
.013 .16
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


DELICIOUS APPLE
MAGNESIUM PERCENT DRY WEIGHT (LEAVES)
1.00
.75
.50
.25
0
L.S. D.
5% 1%
.116 .141
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


ELBERTA PEACH
MAGNESIUM PERCENT DRY WEIGHT (LEAVES)
1.00
.75
.50
.25
0
L. S. D.
5% 1%
.065 .079
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4


CONCORD GRAPE
MAGNESIUM PERCENT DRY WEIGHT (STEMS)
1.00
.75
.50
.25
0
L. S. D.
5% 1%
.046 .056
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

<u>Magnesium</u> (see figure opposite)

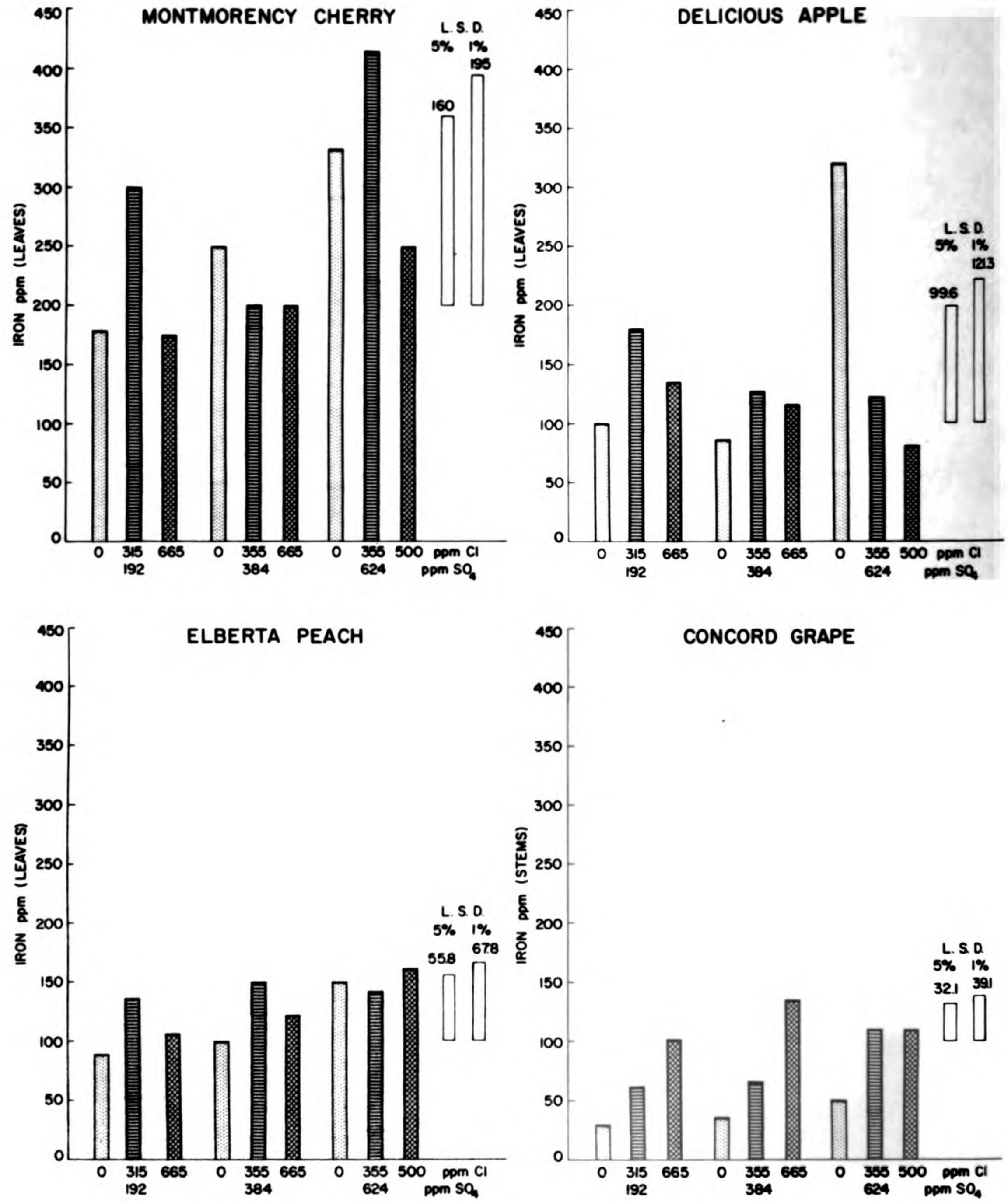
The magnesium content in cherry leaves decreased as the chloride supply was increased from 0 to 315 or 355 p. p. m. within the 192 and 384 p. p. m. sulfate levels. Increasing the chloride concentration from 315 to 665 p. p. m. within the 192 p. p. m. sulfate level did not further reduce the magnesium content. With the 384 p. p. m. sulfate concentration increasing the chloride supply from 355 to 665 p. p. m. increased the magnesium content in cherry leaves while with the 624 p. p. m. sulfate level it did not. As the sulfate supply was increased from 192 p. p. m. in the absence of chloride the magnesium content in cherry leaves was lowered.

Magnesium content in apple leaves increased as the chloride supply was increased within the 192 and 384 p. p. m. sulfate concentrations. Within the 624 p. p. m. sulfate level increasing the chloride supply increased the magnesium content at the 355 p. p. m. chloride level. Increasing the sulfate supply from 192 to 624 p. p. m. in the absence of chloride or with 665 p. p. m. of chloride did not markedly change the magnesium content. Magnesium content was increased by supplying 624 p. p. m. of sulfate with 355 p. p. m. of chloride.

Leaves from peach trees decreased markedly in magnesium content as the chloride supply was increased from 0 to 665 p. p. m. regardless of the sulfate level. Increasing the sulfate supply in the absence of chloride tended to decrease the magnesium content but not when chloride was included in the substrate.

Increasing the chloride supply from 0 to 665 p. p. m. within the 192 and 624 p. p. m. sulfate levels decreased the magnesium content in grape stems. When sulfate was supplied at the 384 p. p. m. level increasing the chloride supply did not reduce magnesium. The quantity of sulfate supplied did not effect the magnesium content regardless of the chloride concentration.

THE


MONTMORENCY CHERRY
DELICIOUS APPLE
ELBERTA PEACH
CONCORD GRAPE
IRON ppm (LEAVES)
IRON ppm (STEMS)
450
400
350
300
250
200
150
100
50
0
L. S. D.
5% 1%
160
195
99.6
121.3
55.8
67.8
32.1
39.1
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4

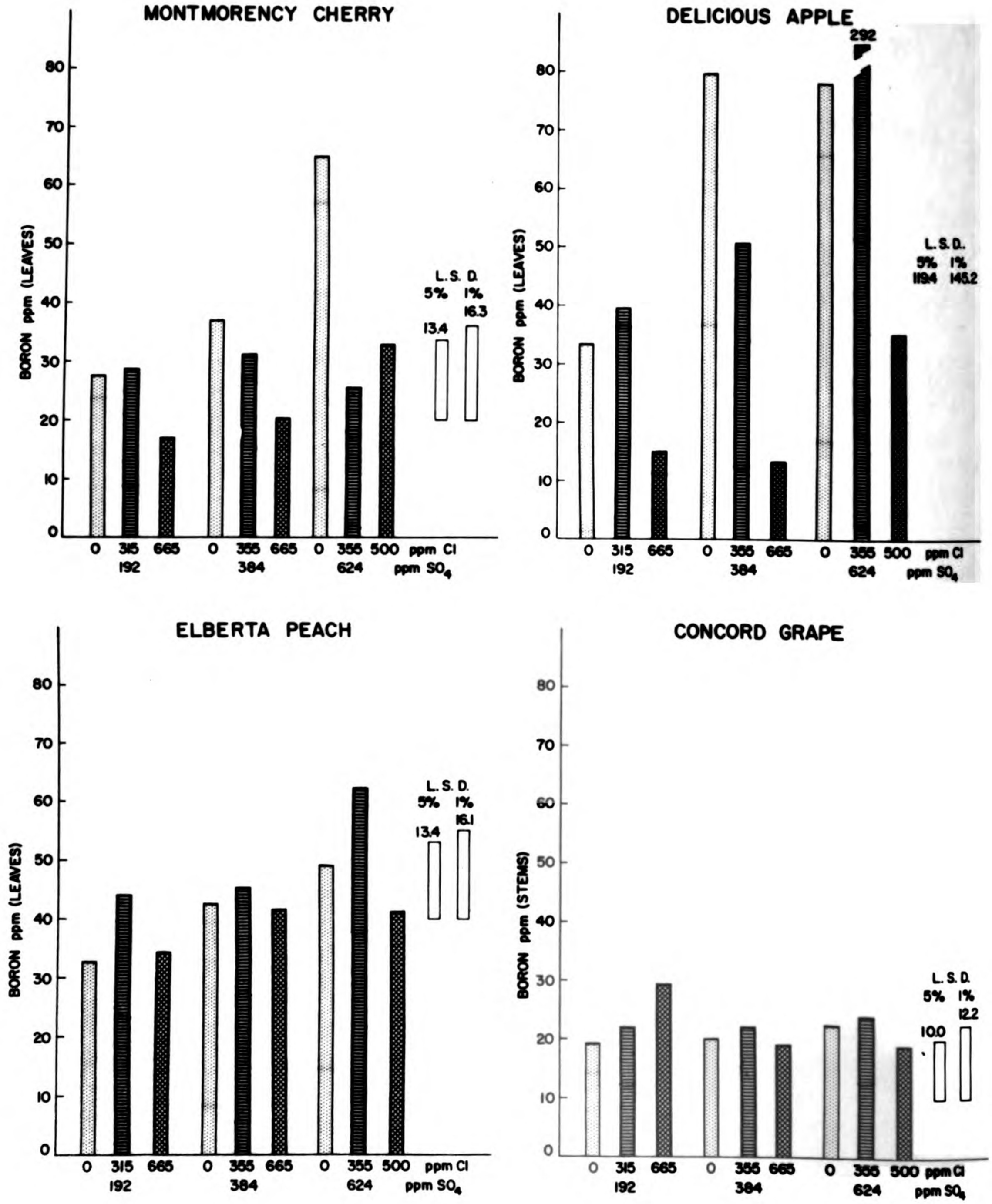
Iron (see figure opposite)

Increasing the chloride supply from 0 to 665 p.p.m. within any sulfate level did not significantly change the iron content in cherry leaves. Iron content in cherry leaves increased as the sulfate supply was increased from 192 to 624 p.p.m. in the absence of chloride. When the sulfate supply was increased from 384 to 624 p.p.m. within the 355 p.p.m. chloride concentration cherry leaves accumulated more iron.

Apple leaves showed no great change in iron content as result of increasing the chloride concentration from 0 to 665 p.p.m. within the 192 and 384 p.p.m. sulfate levels. However, higher levels of chloride reduced iron when 624 p.p.m. of sulfate was used. Increasing the sulfate supply from 192 to 384 p.p.m. did not change the iron content in apple leaves while increasing the sulfate supply from 384 to 624 p.p.m. in the absence of chloride markedly increased it.

Iron content in peach leaves increased then decreased slightly as result of increasing the chloride supply from 0 to 665 p.p.m. within the 192 and 384 p.p.m. sulfate concentrations but in the 624 p.p.m. sulfate level it did not. In the absence of chloride or when supplied with 665 p.p.m. of chloride, increasing the supply of sulfate from 192 to 624 p.p.m. increased iron content in peach leaves.

Increasing the chloride supply from 0 to 665 p.p.m. increased the iron content in grape stems more as the sulfate concentration was increased from 192 to 624 p.p.m. When sulfate was supplied without chloride no great change in iron content in grape stems was observed. However, when chloride was included in the nutrient solution increasing the sulfate supply from 192 to 624 p.p.m. increased the iron content.


MONTMORENCY CHERRY
BORON ppm (LEAVES)
0 10 20 30 40 50 60 70 80
L. S. D.
5% 1%
13.4 16.3
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4
DELICIOUS APPLE
292
BORON ppm (LEAVES)
0 10 20 30 40 50 60 70 80
L. S. D.
5% 1%
119.4 145.2
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4
ELBERTA PEACH
BORON ppm (LEAVES)
0 10 20 30 40 50 60 70 80
L. S. D.
5% 1%
13.4 16.1
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4
CONCORD GRAPE
BORON ppm (STEMS)
0 10 20 30 40 50 60 70 80
L. S. D.
5% 1%
10.0 12.2
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4

Boron (see figure opposite)

The boron content in cherry leaves did not change as the chloride supply was increased from 0 to 315 p.p.m. with the 192 p.p.m. sulfate concentration while increasing the chloride supply to 665 p.p.m. markedly reduced it. With the 384 p.p.m. sulfate, increasing the chloride concentration reduced boron accumulation. Increasing the sulfate supply from 192 to 624 p.p.m. in the absence of chloride increased boron accumulation. The depressing effect of the 665 p.p.m. chloride concentration on boron accumulation was counterbalanced by increasing the sulfate supply.

Apple leaves tended to contain less boron as the chloride supply was increased from 0 to 665 p.p.m. with the 192 and 384 p.p.m. sulfate concentrations. At the 624 p.p.m. sulfate level boron increased markedly then decreased as the chloride supply was increased from 0 to 500 p.p.m. Increasing the sulfate supply from 192 to 624 p.p.m. in the absence of chloride, or when 665 p.p.m. of chloride was included, slightly increased the boron content while with 355 p.p.m. of chloride it was increased markedly.

Peach leaves increased then decreased in boron as the chloride supply was increased from 0 to 665 p.p.m. with the 192 and 624 p.p.m. sulfate concentrations. Increasing the sulfate supply from 192 to 624 p.p.m. increased the boron content in peach leaves regardless of the chloride level.

The boron content in grape stems increased as the chloride supply was increased from 0 to 665 p.p.m. with the 192 p.p.m. sulfate level but had no effect with the 384 or 624 p.p.m. sulfate concentrations. Increasing the sulfate supply did not influence boron accumulation in grape stems regardless of the chloride concentration.

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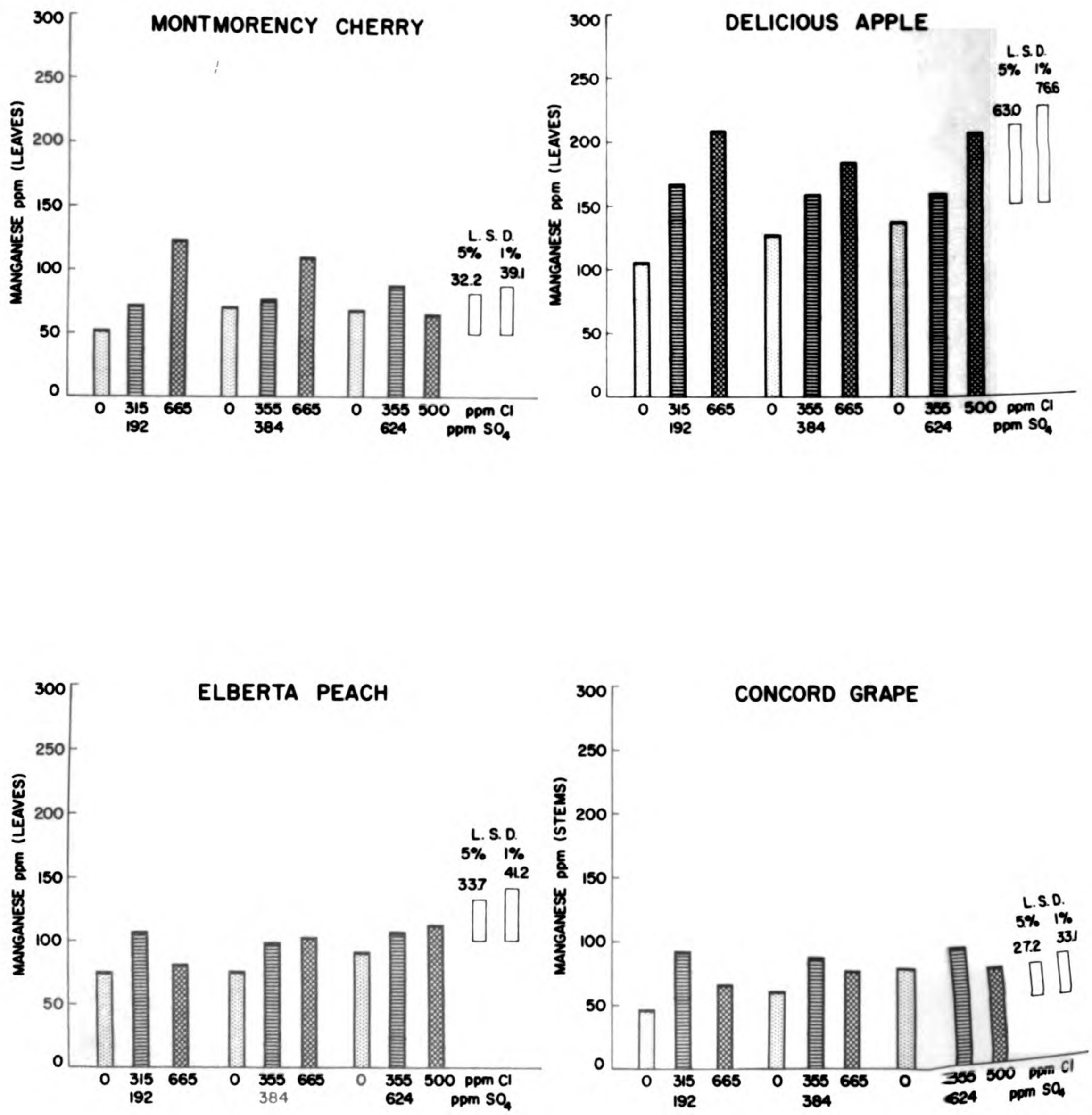

MONTMORENCY CHERRY
DELICIOUS APPLE
ELBERTA PEACH
CONCORD GRAPE
MANGANESE ppm (LEAVES)
MANGANESE ppm (STEMS)
L. S. D.
5% 1%
32.2 39.1
63.0 76.6
33.7 41.2
27.2 33.1
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO_4

Manganese (see figure opposite)

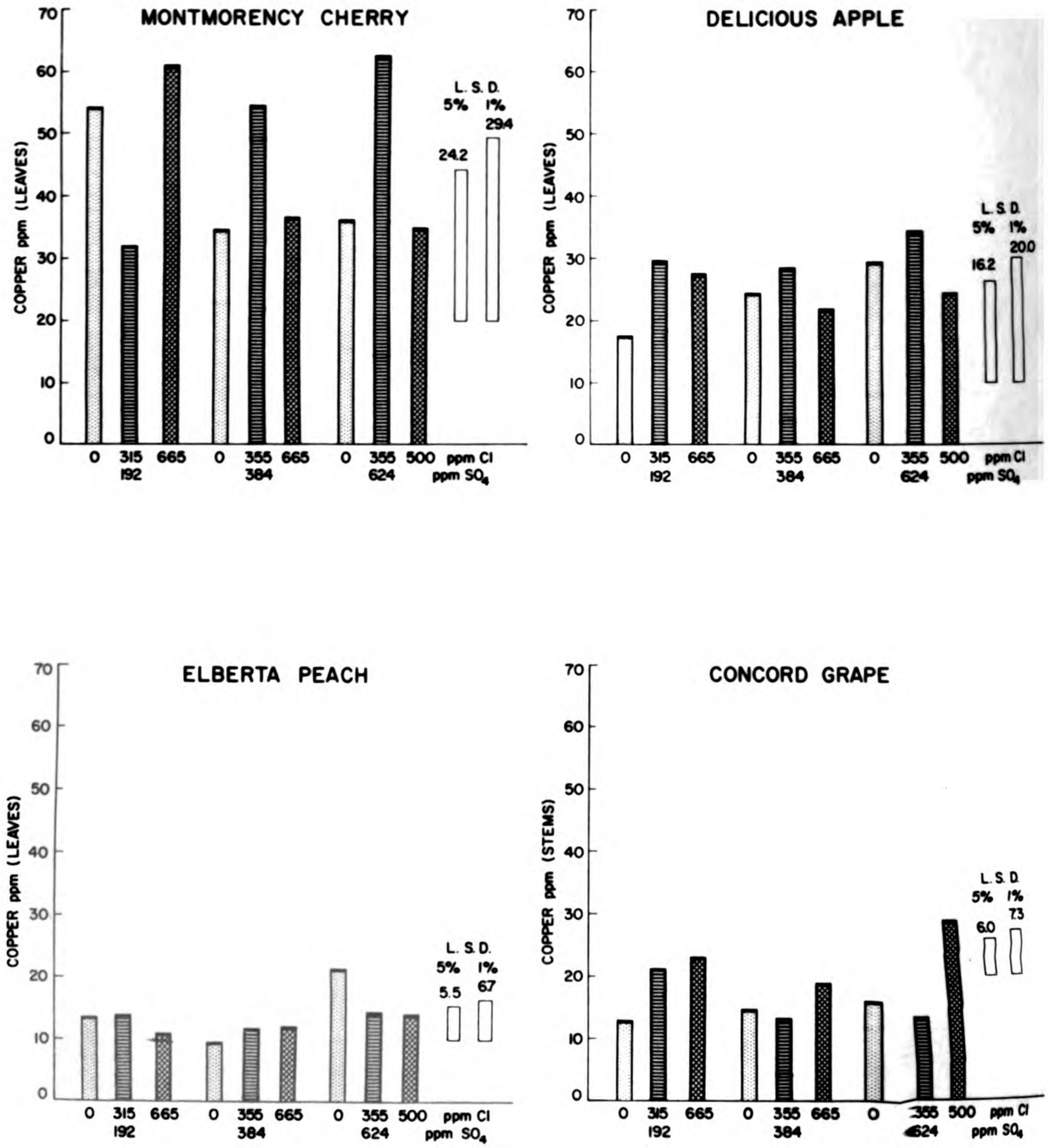
A linear increase in the manganese content in cherry leaves resulted when the chloride supply was increased from 0 to 665 p.p.m. with the 192 and 384 p.p.m. sulfate levels but not at the 624 p.p.m. sulfate level. Increasing the sulfate supply from 192 to 624 p.p.m. reduced manganese accumulation only in the presence of the 665 p.p.m. chloride concentration.

Apple leaves increased in manganese content as the chloride supply was increased from 0 to 665 p.p.m. regardless of the sulfate supply. Increasing the sulfate supply from 192 to 624 p.p.m. tended to reduce the stimulatory influence of chloride on manganese absorption.

Peach leaves tended to increase in manganese as the chloride supply was increased from 0 to 665 p.p.m. with the 384 and 624 p.p.m. sulfate concentrations. Increasing the sulfate concentration increased manganese accumulation in peach leaves only in the presence of the 665 p.p.m. chloride concentration.

Manganese increased then decreased in grape stems as the chloride supply was increased from 0 to 665 p.p.m. with all sulfate levels. Increasing the sulfate supply from 192 to 624 p.p.m. to grape plants not receiving chloride increased the manganese content. The stimulating effect of sulfate on manganese accumulation was less pronounced as chloride was added to the nutrient solution.

THE.



MONTMORENCY CHERRY
DELICIOUS APPLE
ELBERTA PEACH
CONCORD GRAPE
COPPER ppm (LEAVES)
COPPER ppm (STEMS)
0
10
20
30
40
50
60
70
L. S. D.
5% 1%
24.2 29.4
16.2 20.0
5.5 6.7
6.0 7.3
0 315 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

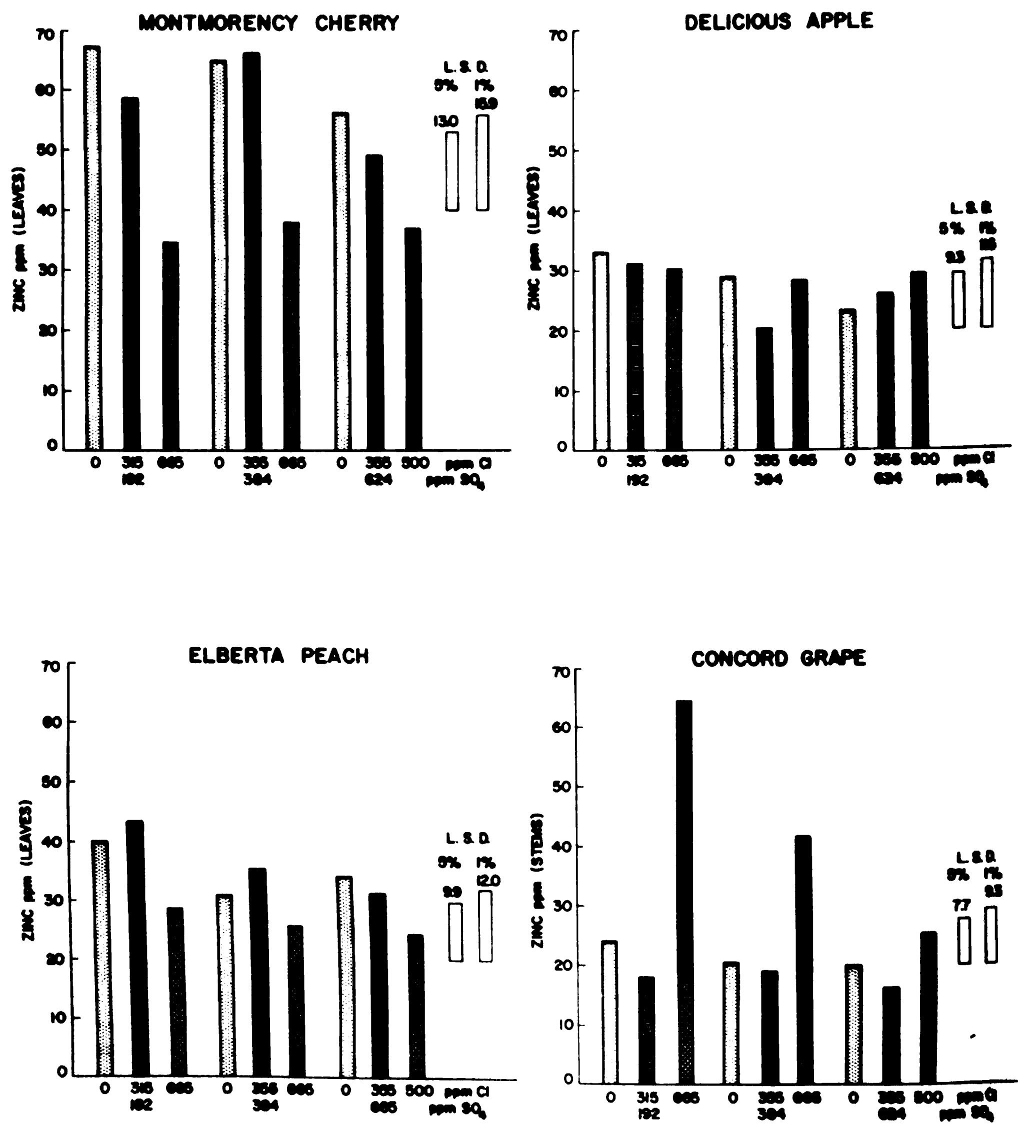
<u>Copper</u> (see figure opposite)

Increasing the chloride supply from 0 to 665 p. p. m. decreased then increased the copper content in cherry leaves from trees receiving 192 p. p. m. of sulfate. The exact reverse occurred when chloride was increased with the 384 and 624 p. p. m. sulfate levels. Increasing the sulfate supply from 192 to 624 p. p. m. in the absence of chloride, or with 665 p. p. m. of chloride, depressed copper accumulation and increased it when 355 p. p. m. of chloride was included.

Copper content in apple leaves tended to be higher when chloride was supplied at the 355 p. p. m. concentration. Increasing the sulfate supply tended to increase the copper content though the differences were not significant.

Peach leaves did not vary significantly in copper content as the chloride supply was increased from 0 to 665 p. p. m. regardless of the sulfate concentration. Increasing the sulfate supply from 192 to 624 p. p. m. in the absence of chloride decreased then increased the copper content in peach leaves. When supplied with chloride, however, increasing the sulfate supply did not increase the copper content.

Increasing the chloride supply from 0 to 665 p. p. m. increased the copper content in grape stems regardless of the sulfate concentration. However, when supplied with 384 or 624 p. p. m. of sulfate, copper increased only when supplied with 665 p. p. m. of chloride. In the absence of chloride increasing the sulfate supply did not alter the copper content while increasing the sulfate within the 355 p. p. m. chloride concentration increased the copper content.


MONTMORENCY CHERRY
ZINC ppm (LEAVES)
L. S. D.
5% 1%
13.0 15.9
DELICIOUS APPLE
ZINC ppm (LEAVES)
ELBERTA PEACH
ZINC ppm (LEAVES)
L. S. D.
5% 1%
9.9 12.0
CONCORD GRAPE
ZINC ppm (STEMS)
L. S. D.
5% 1%
7.7 9.5
0 315 665 0 365 665 0 365 500 ppm Cl
192 384 624 ppm SO_4

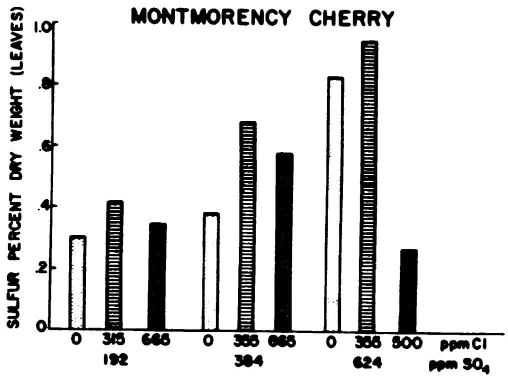
Zinc (see figure opposite)

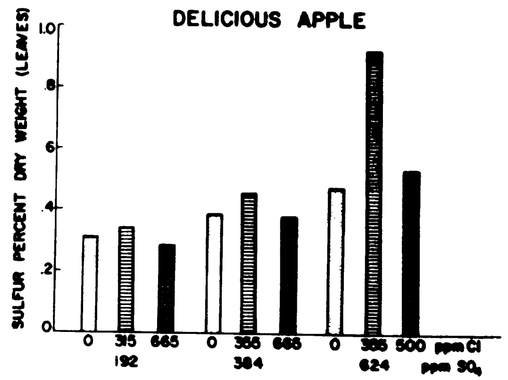
Cherry leaves decreased in zinc as the chloride supply was increased from 0 to 665 p. p. m. regardless of the sulfate concentration. The 315 or 355 p. p. m. chloride concentration did not markedly change zinc content while the 665 p. p. m. concentration reduced it. Increasing the sulfate supply from 384 to 624 p. p. m. reduced zinc absorption when supplied with 355 p. p. m. of chloride.

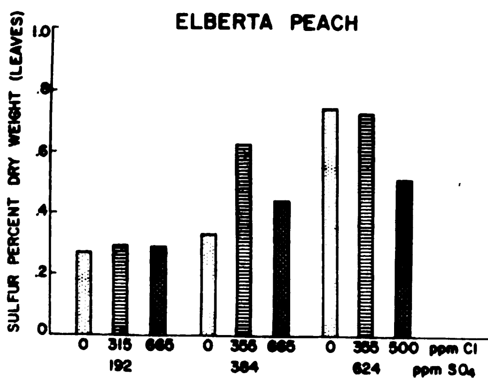
Zinc content in apple leaves did not vary significantly as result of increasing the chloride supply from 0 to 665 p. p. m. regardless of the sulfate level. Increasing the sulfate supply from 192 to 624 p. p. m. in the absence of chloride or when supplied with 355 p. p. m. of chloride tended to decrease zinc accumulation.

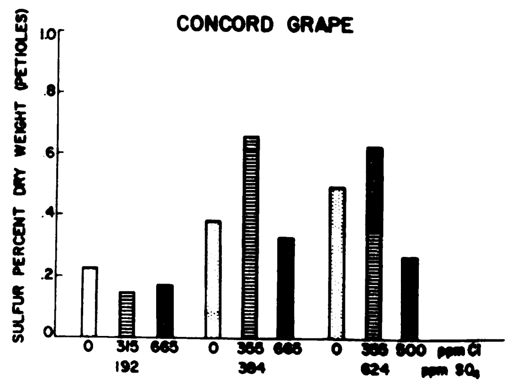
Increasing the chloride concentration from 0 to 665 p. p. m. within the 192 or 384 p. p. m. sulfate levels slightly increased then decreased zinc accumulation in peach leaves. At the 624 p. p. m. sulfate concentration zinc accumulation decreased linearly as the chloride supply was increased. As the sulfate supply was increased from 192 to 624 p. p. m. in the absence of chloride or when 665 p. p. m. of chloride was included the zinc content was not changed while including 355 p. p. m. of chloride decreased it.

Zinc content in grape stems was not markedly changed by increasing the chloride supply from 0 to 355 p. p. m. regardless of the sulfate concentration. At the 665 p. p. m. chloride concentration zinc accumulation was greatly increased. Increasing the sulfate supply from 192 to 624 p. p. m. in the absence of chloride or when 355 p. p. m. of chloride was added did not change the zinc content while increasing the sulfate with 665 p. p. m. of chloride counteracted the stimulating effect of high chloride on zinc accumulation.


MONTMORENCY CHERRY
SULFUR PERCENT DRY WEIGHT (LEAVES)
1.0
.8
.6
.4
.2
0
0 315 665 0 365 665 0 365 500 ppm Cl
192 384 624 ppm SO4


DELICIOUS APPLE
SULFUR PERCENT DRY WEIGHT (LEAVES)
1.0
.8
.6
.4
.2
0
0 315 665 0 365 665 0 365 500 ppm Cl
192 384 624 ppm SO4


ELBERTA PEACH
SULFUR PERCENT DRY WEIGHT (LEAVES)
1.0
.8
.6
.4
.2
0
0 315 665 0 365 665 0 365 500 ppm Cl
192 384 624 ppm SO4


CONCORD GRAPE
SULFUR PERCENT DRY WEIGHT (PETIOLES)
1.0
.8
.6
.4
.2
0
0 315 665 0 365 665 0 365 500 ppm Cl
192 384 624 ppm SO4

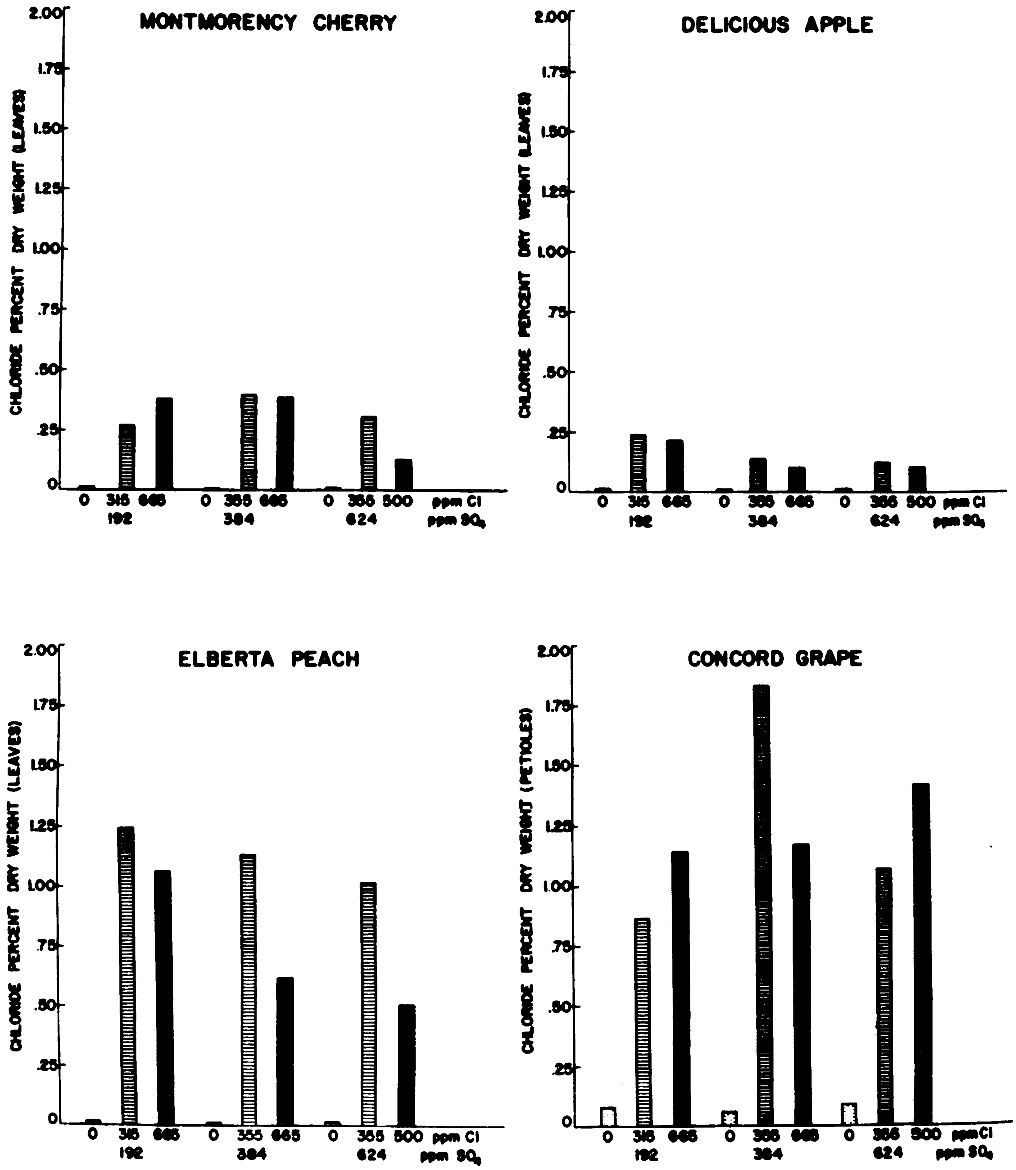
<u>Sulfur</u> (see figure opposite)

Sulfur content increased then decreased in cherry leaves as the chloride concentration was increased from 0 to 665 p. p. m. regardless of sulfate supply. At the high sulfate level, high chloride markedly depressed sulfur accumulation. Increasing the sulfate supply in the absence of chloride or when supplied with 355 p. p. m. chloride brought about a linear increase in the sulfur content in cherry leaves. Chloride depressed sulfur accumulation when both were supplied in high concentration.

Apple leaves increased then decreased in sulfur as the chloride supply was increased from 0 to 665 p. p. m. especially when increased within the high sulfate concentration. Increasing the sulfate supply from 192 to 624 p. p. m. increased the sulfur content in apple leaves more when supplied with 355 p. p. m. of chloride than when supplied without chloride or with 665 p. p. m. of chloride.

Increasing the chloride level from 0 to 665 p. p. m. did not change the sulfur content in peach leaves from trees supplied with 192 p. p. m. sulfate. When supplied with 384 p. p. m. of sulfate, chloride increased then decreased sulfur accumulation. At the 624 p. p. m. sulfate level, increasing the chloride supply from 0 to 500 p. p. m. decreased the sulfur content in peach leaves. Increasing the sulfate supply from 192 to 624 p. p. m. increased sulfur content in peach leaves more when supplied with a moderate amount of chloride than with a high amount of chloride.

The high chloride level (665 p. p. m.) decreased and the moderate chloride level (355 p. p. m.) increased sulfur content in grape petioles from plants supplied with 384 and 624 p. p. m. sulfate while chloride did not influence sulfur content in plants receiving 192 p. p. m. of sulfate. Sulfur content in grape petioles increased more with increasing sulfate supply in the presence of a moderate chloride concentration than in the absence of chloride or in the presence of a high level.


MONTMORENCY CHERRY
DELICIOUS APPLE
ELBERTA PEACH
CONCORD GRAPE
CHLORIDE PERCENT DRY WEIGHT (LEAVES)
CHLORIDE PERCENT DRY WEIGHT (PETIOLES)
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
0
0 316 665 0 355 665 0 355 500 ppm Cl
192 384 624 ppm SO4

Chlorine (see figure opposite)

Cherry leaves contained more chloride as the supply in the nutrient solution was increased from 0 to 665 p. p. m. within the 192 and 384 p. p. m. sulfate levels. In the presence of 624 p. p. m. of sulfate increasing the chloride supply increased then decreased the quantity of chloride recovered in cherry leaves. Increasing the sulfate supply to 624 p. p. m. decreased the chloride content in cherry leaves from trees supplied with 500 p. p. m. chloride.

The chloride content in apple leaves increased then decreased slightly as the concentration in the nutrient solution was increased from 0 to 665 p. p. m. regardless of the sulfate level. The 384 and 624 p. p. m. sulfate concentrations reduced the chloride content in apple leaves from trees supplied with moderate and high chloride levels.

Peach leaves increased then decreased slightly in chloride content as the supply was increased from 0 to 665 p. p. m. The decrease in chloride content at the high chloride level was accentuated as the sulfate supply was increased from 192 to 624 p. p. m. Increasing the sulfate supply from 192 to 624 p. p. m. reduced the amount of chloride recovered in peach leaves from trees supplied with moderate and to a greater extent high chloride concentrations.

The amount of chloride recovered in grape petioles was linear with supply in the nutrient solution when supplied with 192 or 624 p. p. m. of sulfate. At the 384 p. p. m. sulfate concentration chloride content in grape petioles increased then decreased as the chloride supply was increased from 0 to 665 p. p. m. Increasing the sulfate supply from 0 to 384 p. p. m. accentuated chloride accumulation in grape petioles from plants receiving the moderate chloride level. High chloride and high sulfate in combination accentuated chloride accumulation.

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DISCUSSION

Although the concentration of essential elements, except chloride and sulfate, was maintained at a constant level, marked differences in growth and leaf composition resulted. Since the supply of elements was kept constant, variation in growth and leaf composition can be contributed to specific anion effects.

Increasing the supply of chloride to a high level (665 p. p. m.) resulted in an apparent toxicity as measured by severe growth depression in all crops. On peach trees receiving a high chloride - low sulfate solution the leaves showed marginal scorch ---a symptom described by Hayward and Long (23) and others (5), (18), (22), (42) as chloride toxicity.

Increasing the sulfate supply did not adversely effect growth of apple, peach, and grape; but depressed growth of cherry trees.

Parups (42) reported that sulfate and chloride were absorbed by cherry trees in direct proportion to their supply in the substrate. This was not found to be true for all crops under the conditions of this experiment. Greater quantities of chloride were recovered in apple and peach leaves from the medium rather than the high chloride level. Sulfate appeared to reduce chloride absorption. This effect was accentuated for all crops as the sulfate supply was increased in the culture medium. The sulfur content in the leaves of all crops increased with increasing sulfate supply in the absence of chloride. As the chloride level increased there was first a stimulation then a depression in sulfur accumulation in the leaves of all crops.

It was quite apparent that the reduction in growth of all, and the development

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of visible toxicity symptoms in some, plants was a direct result of the chloride concentration in the nutrient solution. Supplied with the same chloride concentration, the growth of all plants was depressed nearly the same magnitude. Since chloride ions are freely absorbed, an accumulation of chloride ion in the leaves should have been related to growth. The highest chloride content found in cherry leaves was 0. 4; in apple - 0. 24; in peach - 1. 24; and in grape petioles - 1. 82 per cent of their dry weight. The chloride content in cherry and apple leaves was considerably lower than found in peach leaves and grape petioles yet growth response was very similar. The greatest growth depression occurred in cherry trees when the chloride content in the nutrient solution was highest. This was not true for apple, peach and grape.

Peach leaves having the highest and nearly the same chloride content, exhibited two entirely different leaf symptoms, depending on the chloride - sulfate supply in the substrate. Marginal scorch occurred with the high chloride - low sulfate solution; but interveinal "shot-hole" necrosis occurred with medium chloride - high sulfate or medium chloride - medium sulfate solutions. The latter two solutions developed blotchy-necrotic leaf symptoms on grape.

Inasmuch as the chloride content in the leaves of apple, peach, and petioles of grape cannot be entirely responsible for growth depression, the effect of chloride may have been expressed as limiting the absorption or utilization of some other element(s) or necessary growth factor.

There was an inverse relationship between chloride and potassium in the leaves. However, the chloride content in the leaves was not always highest

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when potassium content was lowest in the leaves. High chloride content in the nutrient solution always resulted in a lower potassium content of the leaves. This would infer that the depressing effect of chloride on potassium accumulation was exerted during absorption by roots. Overstreet et. al. (41) report decreased potassium absorption by barley roots as the concentration of potassium chloride increased in the substrate. Potassium and chloride ions are absorbed by roots by two distinctly different mechanisms and would therefore not be expected to compete with each other for metabolic "binding sites" according to Epstein (14).

Several workers (11), (45), (58), have reported that the accumulation of chloride cirectly or indirectly interfers with potassium accumulation in several plants. In studies where the concentration of essential elements was kept constant and the chloride level increased, Parups (42) found potassium content in cherry leaves decreased markedly.

Boresch (5) theorized that while potassium may be present in adequate amounts for normal plant requirements, there may not be a sufficient quantity to combine with all the chlorine in the leaves. According to him, the excess chloride is combined with calcium and an antagonism between potassium and calcium produces the symptoms of potassium deficiency. This concept seems inadequate to explain the expression of symptoms on two counts; dissociation phenemenon regarding calcium chloride salts could not effect tie up calcium because the chloride ion can be extracted quantitatively from leaf tissue by water; and the chloride ion accumulates under conditions of excess supply in quantities greater than calcium absorption could account for.

Sideris and Young (52) conclude from their work with pineapple

> "that the terminal leaf necrosis of pineapple is affected by changes in the metabolic condition of the tissues resulting from high chloride concentration in association with potassium deficiency. Pineapple plants amply supplied with potassium even in the presence of high chloride concentration failed to develop leaf necrosis. The chemical differences in leaf tissue composition between plants with ample and with deficient potassium are expressed mainly in the concentration of starch and sugars. It is possible that starch and sugars produced with ample potassium increase the tolerance of the cells to high chloride concentrations."

The physiological response to chloride ion may be the result of enzyme activation brought about by the increased acidity of the plant cells due to chloride. Large increases in acidity changes the acceleration to an inhibition of enzyme activity according to Haas (19). The marked changes in the organic acid metabolism in tobacco leaves, Anderson, et. al. (1) and barley roots Jacobson and Ordin (27), induced by excessive anion accumulation may be reflected by acceleration or inhibition of essential enzyme systems related to cellular activities associated with carbohydrate utilization.

To compare the leaf composition of crops grown in the greenhouse to leaf composition of the same crops grown in the field is not completely valid. A comparison of low, high and average values observed in the field to those obtained in the greenhouse may, however, gove some insight to growth responses that occurred. Under field conditions Kenworthy (30) found the following average composition in cherry, apple, and peach leaves.

	Per cent of dry weight								
	N	P	K	Ca	Mg	Mn	Fe	Cu	B
Montmorency cherry	2.83	.267	1.54	1.91	.74	.0114	.028	.0055	.0067
Jonathan apple	2.45	.232	1.65	1.58	.44	.0112	.021	.0010	.0057
Elberta peach	3.79	.243	1.56	1.92	.71	.0101	.023	.0016	.0060

When these values are compared to the values for the check treatment (0-chloride and 192 p.p.m. sulfate) it is seen that the potassium values are considerably higher than those found in the field. With the exception of potassium, the leaf composition of peach compares quite closely to field averages. The composition of cherry leaves grown in the greenhouse varied considerably above and below field averages - nitrogen was higher and phosphorus, boron, iron and manganese were lower. Greenhouse apple leaves were higher in nitrogen and calcium but the remaining elements compared favorably with field averages. A composition comparison of greenhouse grown grapes to those grown in the field was not possible because stem analysis could not be compared to petiole analysis available for field conditions.

Though chloride depressed potassium accumulation in cherry, apple and peach the level was still considerably above averages considered deficient in the field. The same was true for calcium in cherry, magnesium in peach and cherry, and boron in cherry and apple. The low calcium content in apple and peach leaves from high sulfate treatment was still above values considered de-

ficient in the field. The high sulfate - medium chloride solution reduced calcium content in peach leaves to a low level which was still considered adequate according to field data.

The tolerance of plants to chloride injury varies widely depending upon species and prevailing climatic conditions. Environmental conditions which favor high transpiration rates are conducive to salt injury on plants (such as, squash, tomatoes and alfalfa) when supplied with high salt concentrations according to Magistad et. al. (36). Neller (37) reported that plants growing in soils high in organic matter can tolerate more chloride than plants growing in sandy soils.

The chloride content in the soils varies widely depending upon the use of fertilizers containing chloride, proximity to waters containing chloride, deposition of chloride salts during the soil forming process and the degree of leaching that has progressed.

When fertilizer is applied to a soil and conditions conducive to leaching prevail, loss of nutrients in drainage water is likely to occur. The proportion of the component ions in the drainage water usually deviates from those added in the fertilizer because of cation and anion exchange reactions in the soil. This is well illustrated by the observations of Volk and Bell (59) on lysimeters filled with a loamy fine sand having a base exchange capacity of 3. 0 m. e. per 100 grams. Various sodium, magnesium, and potassium salts were applied to different lysimeters. Though no calcium was applied it was the predominant cation recovered in the drainage water. Only 1 per cent of the potassium; 65 per cent of the sodium; and 30 per cent of the magnesium applied was recovered

in the leacate. However, chlorides were recovered almost quantitatively; about 50 per cent of the sulfates and almost twice as much nitrate was recovered as was applied. There was practically no difference in the proportion or content of cations in the leachate, whether the salts added were chlorides or nitrates; but when sulfate salts were applied there was a marked decrease in the loss of calcium.

From these results of Volk and Bell (59) it would be infered that the chloride ion would not accumulate in soils. However, the ability of a soil to retain chloride depends somewhat upon soil type and structure, Wilklander (62). According to Toth (56) and Wilklander (62) acid clay soils retain more chloride than the same soils with higher pH values.

The effect of chloride ion on promoting loss of nutrients in the soil, mainly calcium, and its depressing effect on the absorption of certain elements, especially potassium, by fruit trees, may be of considerable importance. Fruit trees growing on light soils deficient in these elements, under conditions of limited rainfall, where loss of chloride through leaching would be minimized, quite possibly may be injured by large applications of fertilizers containing chloride. The chloride ion, being freely mobile in soils with low exchange capacities, may concentrate in the soil solution as the moisture supply is diminished by the trees. Fertilizer may be applied to a limited area around fruit trees. If this rate of application to a few square feet is converted to an acre basis, the application may amount to several thousand pounds per acre. Relatively heavy applications of potassium chloride may approach the concentrations used in this experiment. However, the application is not renewed during

the season and any toxic effects of the relatively high chloride level would be of short duration. This may account for the lack of visible symptoms of chloride toxicity under field conditions.

The buffering effect of soil organic matter, colloidal clay, and bicarbonate on rendering plants more resistant to chloride injury coupled with loss of chloride through leaching reduces the hazard of using fertilizers containing chloride. Beneficial effects of liming to reduce chloride injury according to Wheeler and Hartwell (61) and Piland and Willis (44) further reduce the hazard of using chloride fertilizers. Avoiding the use of an ammonium form of nitrogen when using fertilizers containing chloride has been recommended by Buchner (7).

Potassium fixation does not appear to be related to the form in which it is supplied. F ctors governing the adsorption of chloride by soil colloids and accumulation of chloride in plants, may result in less potassium ions accumulated in plants supplied with the chloride form of potassium as compared to the sulfate or carbonate forms. There are some indications that this occurs under field conditions, Kenworthy (31), Vinet (58). However, the evidence does not warrant avoiding the use of potassium chloride as a fertilizer if used with consideration to existing soil and climatic conditions and crop being grown.

SUMMARY

The specific influence of chloride and sulfate anions, used singly and in combination, upon growth and leaf composition of Montmorency cherry, Delicious apple, and Elberta peach, and Concord grape was studied by the means of nutrient solution methods.

Three levels of chloride and sulfate were employed in a factorial design giving nine treatment combinations without altering the metallic cation content of Hoagland's (24) nutrient solution. This was accomplished by using different amounts of various chemicals containing the anions involved.

Growth was measured as linear growth of shoots and dry weight of various plant parts - leaves, shoots, fibrous roots, and trunk. Increase in total dry weight was calculated. Leaves from each tree and stems[1] from each grape plant were analyzed for twelve elements: nitrogen, phosphorus, potassium, calcium, magnesium, iron, boron, manganese, copper, zinc, sulfur and chlorine.

Increasing the supply of chloride decreased all measurements of growth for all crops and produced leaf symptoms of chloride toxicity on peach and grape.

Increasing the sulfate supply did not adversely affect the growth of apple, peach, and grape; but depressed growth of cherry trees.

Increasing the supply of chloride and sulfate together depressed growth in proportion to the chloride level.

The chloride content in cherry leaves and grape petioles was directly

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[1] See footnote page 13.

proportional to supply. Apple and peach leaves contained more chloride when supplied with a medium chloride level. Increasing the sulfate level apparently reduced chloride absorption for all crops.

Sulfur content in all plants increased with supply in the absence of chloride. High chloride levels depressed sulfate absorption for all crops.

Moderate and high chloride levels depressed potassium absorption in cherry, apple, and peach while high chloride levels favored potassium absorption in grape plants. Sulfate did not reduce potassium absorption in any crop.

Increasing the level of chloride in the solution increased nitrogen in peach and grape; manganese in cherry, apple and peach; copper and zinc in grape: and decreased; potassium in cherry, apple and peach; calcium in cherry and peach; magnesium in peach and grape; and boron in cherry.

Increasing the sulfate level in the solution increased nitrogen in peach; phosphorus in cherry and peach; iron in peach and grape; boron in cherry, apple and peach. Higher levels of sulfate decreased calcium in cherry, apple and peach; and zinc in peach and grape.

Chloride and sulfate in combination increased the concentration of nitrogen in peach and phosphorus in cherry and decreased calcium in cherry and peach more than when applied separately. Iron content in apple and zinc content in grape was depressed more when chloride and sulfate were supplied in combination than when applied singly.

Although growth depression for all crops with increasing chloride or sulfate in the nutrient solution was of the same magnitude, this could not be attributed

solely to the concentration of chloride in the leaves. The low or high level of certain elements induced by chloride or sulfate levels were not considered inadequate or toxic for growth according to field observations. However, the relative proportions of certain elements in the leaves induced by unequal anion supply and absorption may have been a factor causing reduction in growth. Conversely, the accumulation of certain ions in the leaves may have been the result of reduced growth and not necessarily the result of absorption as influenced by chlorides.

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Table 1 MILLILITERS OF 0.5 M STOCK SOLUTION USED TO OBTAIN ONE LITER OF NUTRIENT SOLUTION CONTAINING THE VARIOUS SULFATE-CHLORIDE CONCENTRATIONS

Nutrient Solution Concentration-ppm		Milliliter 0.5 M Stock Solution Used									
SO_4	Cl	KH_2PO_4	KNO_3	$MgSO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	K_2SO_4	NH_4NO_3	Ca(Cl)2	Mg(Cl)2	KCl
192	0	2	10	4	10						
192	315	2	2	4	10		4	3			
192	665	2		4	10	4	5				
384	0	2			10	4				4	10
384	355	2	10	4		4		5	10		
384	665	2	10	4		9			10		
624	0	2				4		10	10	4	10
624	355	2				8		6	10	4	10
574	500	2				7	5	7	10	4	

Table 2. SULFATE AND CHLORIDE CONCENTRATION (p. p. m.), pH AND CONDUCTIVITY OF NUTRIENT SOLUTIONS

Nutrient Solution Concentration - p.p.m.		pH	Conductivity Mho's x 10^{-5}
SO_4	Cl		
192	0	5.8	210
192	315	5.8	260
192	665	5.6	340
384	0	5.6	220
384	335	5.5	280
384	665	5.6	345
624	0	5.5	240
624	355	5.4	300
574	500	5.4	325

TABLE 3 GROWTH OF MONTMORENCY CHERRY TREES AS INFLUENCED BY VARIOUS SULFATE-CHLORIDE CONCENTRATIONS IN NUTRIENT SOLUTIONS

Nutrient Solution Concentration - p. p. m.		Dry Weight - grams				Linear Growth-cm
SO_4	Cl	Total Increase	Leaves	Shoots	Fibrous Roots	
192	0	71. 8	25. 70	19. 70	11. 70	235. 0
192	315	30. 0	14. 70	7. 23	10. 50	103. 7
192	665	3. 7	6. 03	2. 17	6. 43	34. 7
384	0	40. 9	14. 37	8. 27	8. 97	91. 3
384	355	17. 8	9. 70	3. 83	7. 10	60. 0
384	665	5. 9	6. 37	2. 37	4. 03	41. 7
624	0	44. 4	16. 03	7. 87	11. 73	90. 3
624	355	2. 6	8. 03	3. 30	5. 53	48. 3
574	500	16. 4	9. 37	3. 53	5. 40	65. 0
L. S. D.	5%	30. 2	8. 84	8. 01	5. 11	100. 7
L. S. D.	1%	36. 8	10. 76	9. 75	6. 22	122. 6

Table 4. GROWTH OF DELICIOUS APPLE TREES AS INFLUENCED BY VARIOUS SULFATE-CHLORIDE CONCENTRATIONS IN NUTRIENT SOLUTIONS

Nutrient Solution Concentration - p. p. m.		Dry Weight - grams				Linear Growth-cm.
SO_4	Cl	Total Increase	Leaves	Shoots	Fibrous Roots	
192	0	51.3	22.26	15.87	8.67	179.7
192	315	43.4	19.83	13.10	11.00	149.3
192	665	9.9	9.93	2.43	4.93	47.0
384	0	43.9	19.53	12.33	8.80	160.3
384	355	24.4	13.43	5.90	9.30	101.3
384	665	0.7	6.03	1.70	3.73	53.0
624	0	48.7	23.33	14.80	11.67	166.0
624	355	9.6	9.23	2.73	7.67	65.7
574	500	0.7	4.93	1.47	2.80	60.7
L.S.D.	5%	26.3	5.32	4.30	4.73	45.9
L.S.D.	1%	32.0	6.48	5.23	5.75	55.8

Table 5. GROWTH OF ELBERTA PEACH TREES AS INFLUENCED BY VARIOUS SULFATE-CHLORIDE CONCENTRATIONS IN NUTRIENT SOLUTIONS

Nutrient Solution Concentration - p. p. m.		Dry Weight - grams				Linear Growth - cm
SO_4	Cl	Total Increase	Leaves	Shoots	Fibrous Roots	
192	0	81.5	36.03	19.30	17.50	243.3
192	315	63.3	30.50	13.30	17.23	245.0
192	665	26.7	17.17	4.44	9.77	119.0
384	0	93.6	39.73	20.90	19.50	338.0
384	355	42.0	24.27	7.10	16.07	160.8
384	665	20.1	13.50	3.27	7.10	97.3
624	0	69.4	35.70	16.10	20.30	295.0
624	355	12.5	14.43	3.53	11.27	115.0
574	500	13.4	12.83	3.57	7.63	96.3
L.S.D.	5%	17.5	5.13	4.56	4.58	30.1
L.S.D.	1%	21.3	6.24	5.55	5.57	36.6

Table 6. GROWTH OF CONCORD GRAPE CUTTINGS AS INFLUENCED BY VARIOUS SULFATE-CHLORIDE CONCENTRATIONS IN NUTRIENT SOLUTIONS

Nutrient Solution Concentration - p.p.m.		Dry Weight - grams				Linear Growth - cm
SO_4	Cl	Total Increase	Leaves	Shoots	Fibrous Roots	
192	0	78.2	24.0	12.5	14.3	216.3
192	315	69.2	23.7	12.0	13.1	240.3
192	665	26.9	11.0	5.7	6.3	192.7
384	0	80.4	24.7	13.4	16.1	253.7
384	355	80.8	25.1	14.8	18.9	246.0
384	665	23.1	9.5	4.0	5.7	132.3
624	0	89.8	26.2	15.2	20.4	280.6
624	355	59.2	19.2	9.5	15.1	158.3
574	500	34.9	11.8	5.3	9.7	146.7
L.S.D.	5%	30.3	5.34	4.74	6.2	78.7
L.S.D.	1%	31.8	6.50	5.77	7.6	95.8

Table 7. INFLUENCE OF VARIOUS SULFATE-CHLORIDE CONCENTRATIONS ON COMPOSITION OF MONTMORENCY CHERRY LEAVES

Nutrient Solution Concentration - p. p. m.		Leaf Composition - % Dry Weight											
SO_4	Cl	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn	S	Cl
192	0	3.63	.18	3.24	2.54	.90	.0179	.0028	.0161	.0163	.0067	.323	.020
192	315	3.62	.24	2.14	1.45	.72	.0300	.0029	.0216	.0096	.0059	.419	.269
192	665	3.63	.21	1.39	1.16	.74	.0170	.0017	.0373	.0183	.0035	.347	.357
384	0	3.72	.24	2.38	2.02	.78	.0250	.0037	.0213	.0104	.0065	.381	.014
384	355	3.78	.24	1.91	1.22	.65	.0200	.0031	.0229	.0164	.0066	.642	.399
384	665	3.43	.19	1.20	1.18	.85	.0200	.0020	.0330	.0110	.0038	.581	.371
624	0	3.76	.31	2.89	1.58	.71	.0333	.0065	.0208	.0109	.0056	.838	.017
624	355	3.58	.24	1.55	1.17	.75	.0415	.0026	.0264	.0188	.0049	.951	.321
574	500	3.53	.25	1.52	1.02	.67	.0250	.0033	.0197	.0105	.0037	.275	.131
L.S.D.	5%	.49	.014	.58	.43	.13	.0161	.0013	.0032	.0024	.0013		
L.S.D.	1%	.60	.018	.70	.53	.16	.0196	.0016	.0039	.0029	.0016		

Table 8. INFLUENCE OF VARIOUS SULFATE-CHLORIDE CONCENTRATIONS ON COMPOSITION OF DELICIOUS APPLE LEAVES

Nutrient Solution Concentration - p.p.m.		Leaf Composition - % Dry Weight											
SO_4	Cl	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn	S	Cl
192	0	3.21	.19	3.05	.84	.48	.0100	.0034	.0105	.0018	.0033	.314	.013
192	315	3.14	.23	2.26	1.02	.47	.0180	.0040	.0167	.0030	.0031	.340	.240
192	665	3.41	.25	1.75	1.03	.55	.0135	.0015	.0209	.0027	.0030	.282	.208
384	0	3.05	.21	2.84	.75	.46	.0086	.0080	.0125	.0024	.0029	.388	.013
384	355	3.44	.27	2.35	.65	.46	.0127	.0051	.0158	.0028	.0020	.453	.128
384	665	3.31	.21	1.85	.76	.55	.0117	.0013	.0184	.0022	.0028	.381	.100
624	0	3.40	.28	2.95	.37	.43	.0320	.0078	.0137	.0029	.0024	.474	.017
624	355	3.30	.32	2.15	.46	.53	.0123	.0292	.0159	.0034	.0026	.929	.120
574	500	3.39	.24	1.82	.60	.46	.0083	.0035	.0206	.0024	.0029	.512	.106
L.S.D.	5%	.32	.24	.56	.30	.12	.0100	.0119	.0063	.0016	.0009		
L.S.D.	1%	.39	.29	.77	.37	.14	.0121	.0145	.0077	.0020	.0015		

Table 9. INFLUENCE OF VARIOUS SULFATE-CHLORIDE CONCENTRATIONS ON COMPOSITION OF ELBERTA PEACH LEAVES

Nutrient Solution Concentration - p.p.m.		Leaf Composition - % Dry Weight											
SO_4	Cl	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn	S	Cl
192	0	3.94	.13	4.28	1.53	.72	.0090	.0033	.0072	.0014	.0040	.271	.021
192	315	4.07	.19	3.78	1.59	.49	.0137	.0044	.0105	.0014	.0043	.294	1.244
192	665	4.25	.21	2.46	1.05	.40	.0107	.0034	.0080	.0011	.0029	.289	1.068
384	0	3.83	.15	4.23	1.25	.64	.0100	.0043	.00[illegible]2	.0010	.0031	.367	.014
384	355	4.46	.21	3.01	1.00	.53	.0150	.0045	.0099	.0012	.0035	.625	1.137
384	665	4.49	.22	2.42	.97	.40	.0123	.0042	.0102	.0012	.0026	.440	.614
624	0	4.17	.19	4.35	.98	.57	.0150	.0049	.0092	.0021	.0034	.745	.018
624	355	4.55	.23	2.61	.77	.50	.0143	.0062	.0107	.0014	.0031	.735	1.018
574	500	4.55	.23	2.53	.89	.44	.0163	.0041	.0112	.0014	.0024	.512	.502
L.S.D.	5%	.27	.05	.24	.18	.06	.0056	.0013	.0034	.0006	.0010		
L.S.D.	1%	.38	.06	.34	.22	.08	.0068	.0016	.0041	.0007	.0012		

Table 10. INFLUENCE OF VARIOUS SULFATE-CHLORIDE CONCENTRATIONS ON COMPOSITION OF CONCORD GRAPE SHOOTS[1]

Nutrient Solution Concentration - p. p. m.		Shoot Composition - % Dry Weight											
SO_4	Cl	N	P	K	Ca	Mg	Fe	B	Mn	Cu	Zn	S	Cl
192	0	.88	.17	1.21	.33	.20	.0030	.0019	.0049	.0013	.0024	.223	.073
192	315	.95	.21	1.00	.24	.21	.0063	.0022	.0093	.0021	.0018	.148	.868
192	665	1.19	.22	1.60	.33	.16	.0101	.0029	.0067	.0023	.0064	.174	1.133
384	0	.86	.18	1.11	.28	.21	.0037	.0020	.0063	.0015	.0021	.382	.068
384	355	.88	.21	.84	.21	.20	.0067	.0022	.0089	.0013	.0019	.660	1.832
384	665	1.13	.22	1.43	.35	.19	.0135	.0019	.0079	.0019	.0024	.326	1.166
624	0	.93	.19	.95	.24	.23	.0053	.0023	.0080	.0016	.0020	.498	.077
624	355	.99	.21	.67	.20	.21	.0110	.0024	.0094	.0013	.0016	.625	1.068
574	500	1.00	.18	.99	.35	.18	.0110	.0021	.0075	.0029	.0025	.268	1.417
L. S. D.	5%	.16	.05	.51	.08	.05	.0032	.0010	.0027	.0006	.0008		
L. S. D.	1%	.21	.06	.71	.10	.06	.0039	.0012	.0033	.0007	.0009		

[1] Shoot analysis was necessary due to insufficient petioles available for analysis. Sulfur and chloride values, however, were obtained from analysis of petioles.

Date Due
