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Title THE INFLUENCE OF INCREASED BASE SATURATION AND THE CHLORIDE ION ON *FRAGARIA ANANASSA*, BAILEY

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Research was carried out to determine the influence of increasing the percentage base saturation of the soil on the yield of the commercial strawberry. It was found that the effect of increasing the bases in the soils was directly related to the original percentage base saturation. When this original value was below approximately 20 percent, the yield was increased, but when it was above this amount, yield was decreased proportionately. It was postulated that this reduction in yield might be related to a temporary increase in the salt concentration of the soil accompanying the addition of the bases.

Further research was carried out to determine the influence of the chloride ion on commercial strawberries. Three separate experiments were conducted to determine this effect. The first was carried out using transplants from commercial growers. It was found that these plants would die within a two week period if

as little as 250 ppm chloride was added to the nutrient solution. Similar plants could survive with as high as 768 ppm sulfate.

A second experiment was conducted using one year old plants and lower concentrations of chlorides and sulfates. At the end of a two month period, those plants grown at 125 ppm chloride differed significantly in weight from those grown at 62.5 ppm chloride, but did not differ in chloride content or other elements such as phosphorus, potassium, calcium and magnesium.

The results of the first two experiments prompted a field survey to determine whether damage was actually occurring in commercial fields. Damage was attributed to chloride injury when the chloride content of the leaves was in the 0.4-0.5 percent range, and the leaves showed the characteristic marginal necrosis of chloride toxicity. It was found that seven out of twelve of the samples taken were in this range, indicating that chloride damage was occurring.

This latter work showed that poor growth and survival of transplants from different plant sources was directly correlated with their chloride content. It is suggested that subsequent additions of chlorides in the fertilizer applied to young transplants can have a marked effect on plants already at or near a threshold toxicity level.

THE INFLUENCE OF INCREASED BASE SATURATION AND THE CHLORIDE ION ON *FRAGARIA ANANASSA*, BAILEY

by

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INTRODUCTION

Oregon produces around 15,000 acres of commercial strawberries, *Fragaria ananassa*, Bailey annually. This is one of the largest acreages in the United States, but with less acreage, California produces more than Oregon. The reason behind this fact is that California has a longer growing season which enables them to produce two to three crops per year compared to Oregon's one. Since strawberries are of much economic importance in Oregon, the research presented in this paper was begun in an effort to increase the yields of strawberries under Oregon conditions.

The first experiment presented in this paper will deal with the percentage base saturation in soils on which strawberries are being grown commercially. The percent base saturation can be defined as the percent of the cation exchange capacity that is occupied by bases; the remainder is usually filled by hydrogen ions.

This factor is an important item, although it is often overlooked in the maintenance of a good nutrient balance of a soil. The largest quantity of any one base present in an Oregon soil is usually calcium followed in decreasing order by magnesium, potassium and finally sodium in minute quantities.

An attempt was made to determine whether increasing the base saturation had any effect on the yield of strawberries. This problem was instigated when it was determined that several different growers had relatively high yields of fruit from soils that varied greatly in percentage base saturation. Some of the soils were at levels of saturation that are considered to be too low for good production of crops.

The work presented herein deals with the addition of calcium, magnesium and potassium in an attempt to determine whether or not increasing the total base saturation improves the yield of strawberries. The three bases mentioned were added together in an attempt to avoid any harmful effects of adding a large amount of any one ion to the soil and thereby upsetting the nutrient balance of the soil.

The second experiment presented deals with the effect of the chloride ion on strawberries. This research was begun when it was noticed that some of the growers cooperating in the first experiment were applying as much as 750 pounds per acre of a 6-20-20 fertilizer.

Nearly all the potassium used in Oregon is applied as potassium chloride. Using the above figure as a basis, it was determined that this amounts to approximately 250 ppm of chloride in the soil solution if all of it were to be dissolved in two acre inches of soil water.

This concentration would become even higher under the dry conditions experienced during the late summer and early fall.

A brief survey of the literature indicated that the strawberry is very sensitive to the chloride ion as well as to other salts. It was also noted that the different varieties of strawberries vary in their sensitivity to the chloride ion.

Since many of the 15,000 acres of strawberries in Oregon are of the Northwest variety, an experiment was set up to determine the sensitivity of the Northwest strawberry to the chloride ion.

Because of the lack of control over external conditions such as rainfall, this experiment was carried out in the greenhouse in sand culture under conditions where the nutrient supply available to the plants was closely regulated.

In conjunction with the greenhouse work, leaf samples were taken from various fields around the state and tested for their chloride content. This was done to determine if there is damage occurring due to the use of too much chloride in the fertilizer program.

LITERATURE REVIEW

Base Saturation and Hydrogen Ion Concentration

A fairly large amount of research has been carried out dealing with the increase of base saturation of the soils in which crops are grown. This adjustment can be accomplished by either liming or the addition of other bases. Liming usually is concerned only with the addition of calcium to the soil to increase the pH or the calcium content of it. The increase of base saturation can be the addition of calcium or any other base to increase the pH as well as to increase any or all of the bases present in the soil and needed by the plants growing in it. Liming will increase base saturation but it does this, with the exception of dolomite, only through the addition of calcium. This does not supply the need for adjustment of other bases in the soil.

Except in the case of a very strongly acidic soil, liming or increasing the base saturation does not benefit the soil directly by reducing the hydrogen ion concentration.

Hewitt (1952) reported that the factors of soil acidity can be classed as follows:

1. Direct injury by H ions
2. Indirect effects of low pH
    - (a) Physiologically impaired absorption of ions.
    - (b) Increased solubility, to a toxic extent, of Al, Mn and Fe.

(c) Reduced availability of P, partly by interference with Al or Fe.
(d) Reduced availability of Mo.

3. Low base status
   (a) Deficiency of Ca or other bases.

4. Abnormal biotic factors
   (a) Impaired nitrogen cycle and nitrogen fixation.
   (b) Impaired mycorrhizal activity.
   (c) Increased attack of certain pathogens.
   (d) Accumulation of soil organic acids or other toxic compounds due to unfavorable redox conditions.

In the same paper, Hewitt reported that plants growing in pots in the greenhouse could grow at a pH of 4.5. This would indicate that the damage due to low pH in the field is not due to the effect of the hydrogen ions since this is as low as is encountered in most fields. Plants growing in acidic nutrient solution tend to increase the pH. This made it necessary to adjust the pH once a week in this experiment to keep it in the desired range.

Other workers have also reported that plants can grow at even lower pH's than that reported by Hewitt. Arnon and Johnson (1942) grew lettuce, tomatoes and Bermuda grass in nutrient solutions varying in pH from 3.0 to 9.0. This research also included three different levels of calcium at all pH's.

The results showed that no growth occurred at pH 3.0 and growth was restricted but took place at pH 4.0. There was also a marked reduction of growth at pH 9.0. The best growth occurred at pH 4.0 in the high level of calcium. At pH 9.0 the calcium had no effect on the growth of the plants. Higher calcium had no effect on plant growth at a pH of 6.0.

Arnon, Fratzke and Johnson (1942) in a follow-up of the above experiment determined the effect of the lower pH's on the absorption of the various ions. They found that at pH 3.0 there was either a total failure or a great reduction in the absorption of calcium and phosphorus. When the plants were placed in the solution at a pH of 3.0 there was evidence of injury within an hour. This manifested itself as a wilting of the plants. At pH 9.0 there was a marked reduction in phosphorus absorption. At pH 4.0 and 5.0 they obtained evidence of lower calcium concentration within the plants.

Guest and Chapman (1944) tested the effect of pH on citrus seedlings. They grew plants at pH's from 2.0 to 11.0. Those plants at the two extremes died in a short time, while those growing between pH 3.0 and 4.0 became iron chlorotic. This problem was attributed to copper and zinc impurities in the iron source causing them to be unavailable at these low pHs. The plants at pH 3.0 remained green but did not grow. From this they concluded that good growth of citrus would occur between pH 4.0 and 9.7 and that any differences between plants would be due to an indirect effect rather than a direct effect of the hydrogen ions.

In a subsequent experiment reported in the same paper, they reported that citrus seedlings could make good growth at a pH of

3.6. In this experiment nitric acid was used instead of sulfuric acid to bring the pH down to the desired level and a closer watch was kept on the impurities present in the stock solutions.

Pierre (1931) experimented with 13 different soils formed under different climatic conditions and of different degrees of weathering. He found that a good correlation existed between the percentage base saturation and plant yield. Those soils with the highest base saturation had the highest yield of sorghum. The author stated that the "critical hydrogen ion concentration" for the growth of crops varied considerably with different soils; therefore, the hydrogen ion concentration of soils cannot be considered the direct cause of poor plant growth nor the main factor governing plant distribution or the response to liming. The summary of this paper was that the percentage base saturation is a better criterion for the growth of sorghum and barley on acid soils than hydrogen ion concentration or soluble aluminum.

The soil pH can have an effect on the occurrence of diseases and their severity on certain crops. Doyle and MacLean (1960) reported that in a preliminary study of ten soils on which potatoes were grown, scabbiness was generally associated with a high pH, and not with the ratio of calcium to potassium. A greenhouse study was carried out to prove conclusively that the scab was directly related to the pH and not to the calcium to potassium ratio.

In an experiment carried out using citrus as the test crop, Peach (1941) reported that on light sandy soils the percentage base saturation will change from 25 percent to 75 percent in changing the pH from 5.0 to 6.0. This would indicate that the recommended pH of 5.5 to 6.0 for light sandy soils would be more to keep the base saturation in line than to overcome the adverse effects of high hydrogen ion concentration. These soils which he worked with had cation exchange capacities of around 2 to 3 m.e. per 100 grams of soil. This research also pointed out one of the adverse effects of a pH that is too high. It was shown that if the pH was over 6.0, that a zinc deficiency would occur.

It has also been shown that the soil type can have a large effect on the influence of base saturation on yield. Mehlich and Colwell (1943) studied three different soils in which cotton and soybeans were grown. These were a 2:1 type clay (montmorillonite), a 1:1 type clay (kaolinite) and a mixture of these two. All of these soil types were mixed with sand so the base exchange capacity was 4 m.e. per 100 grams of soil. They were then mixed with calcium hydroxide to give base saturations of 20, 40 and 60 percent.

The three different soils reacted quite differently to the varying degrees of base saturation. The 2:1 lattice increased its yield of both crops up to 80 percent while no increase in the 1:1 lattice was obtained beyond 40 percent base saturation. These differences were attributed to the fact that the calcium present was more readily released from the 1:1 type and least from the 2:1. This would make it necessary to have more calcium in the 2:1 lattice type clays. This investigation also attempted to determine if added magnesium would also increase yield. Magnesium was kept constant in one treatment and varied in the other. They found no difference in these treatments.

Allaway (1945) differed slightly in his findings from the report of Mehlich and Colwell. In his research with the same type of soils it was reported that the yield of kaolinitic type soils was also increased by increasing the base saturation up to 80 percent. This difference was attributed to the fact that Mehlich and Colwell's experiment used approximately 100 times less calcium per treatment than was used here.

Another part of this research involved the exchange of calcium with hydrochloric acid. This also indicated that the hydrochloric acid would more easily replace the calcium on the 1:1 type clay than on the 2:1 type clay. This substantiated the hypothesis which Mehlich and Colwell mentioned in the preceding paragraph.

Dawson (1958) determined the effect of base saturation and different levels of calcium on the yield of alfalfa grown on different Oregon soils. In the first experiment, four western Oregon soils were used. These were Astoria silt loam, Melbourne silt loam, Olympic loam and Willamette silt loam. These ranged from a pH of 4.7 to 5.7. The percentage base saturation was adjusted in these soils starting at 40 and going to 100 in units of 20.

These soils all reacted differently to this treatment. The Melbourne soil yielded the best increase between 80 and 100; the Willamette soil and the Olympic soil gave the greatest increase between 40 and 60 percent base saturation; the Astoria soil yielded no differently at 40 percent than at 100 percent base saturation. A possible reason for the Olympic and Melbourne soils not responding at the higher percent base saturation was the abundance of aluminum present in them. Astoria had about 12 m.e. aluminum per 100 grams of soil and Olympic had around 5.5 m.e. per 100 grams of soil.

A second experiment was set up in which plants with their roots split were grown in pots containing the soils mentioned above. These soils were also at the different degrees of base saturation mentioned. Part of the roots were allowed to grow into sand cultures with nutrient solutions, some containing calcium and others not. The added calcium increased yield in both Melbourne and Olympic soils and had no effect on the yield of plants grown in Willamette soils. The author attributed this either to increased calcium in the top or a decreased manganese content of the plant. The second reason is put forward because increased calcium in the plant will decrease the manganese uptake of the plant.

Horner (1936) grew soybean plants in a clay soil which had a base exchange capacity of 62 m.e. per 100 grams of soil. The plants were all grown at the same level of calcium but at differing degrees of base saturation. These were 40, 60, 75, 87.5 and 97 percent. The calcium was kept constant and the percent base saturation was varied by adding other bases. The results indicated that the higher the base saturation the higher the yield. The summary stated: "For the particular soil colloid used in this study, a constant level of exchangeable calcium at 97 percent base saturation was approximately twice as effective in nodule production as it was at 40 percent."

This indicated that two factors control the amount of calcium absorbed: (1) the actual amount present and (2) the percentage base saturation. It would also indicate that it is necessary not only to lime the plants growing in a soil, but also to keep the base saturation high in order to prevent the calcium from being tied up by the soil colloids. No mention was made as to the soil type used in the preceding research.

Albricht (1932) stated that the problems involved with acidic soils were due to calcium deficiency rather than the adverse effect of hydrogen ions. He also went on to show that a certain minimum amount of calcium is necessary in order to bring about nodulation of soybeans. These results led him to believe that the significance of calcium for plants rests on its function as an element in the plant's activities, rather than on that of reducing the hydrogen ion concentration of the soil. Later research has shown that this statement is only partly correct, and in some cases at least, the calcium plays an important role in making other ions available to the plant rather than being necessary to prevent a calcium deficiency in the plant.

Cha and Turk (1949) reported on peaches grown in different types of soils and at different degrees of base saturation. These soils all had the same quantity of bases present but were at different degrees of base saturation. This was accomplished by mixing the soils with varying amounts of sand to get the desired results. They found that there was a linear increase in yield with increasing base saturation in Wyoming bentonite, but that with kaolin-sand mixtures there was no increase in yield beyond 40 percent base saturation. The plants growing in these soils also varied in their chemical composition as the base saturation varied. In the bentonite soils, increasing the base saturation from 20 to 80 percent changed the percent of calcium from 18.2 to 32.3 m.e. per 100 grams of tissue and the magnesium from 3.1 to 22.6 m.e. per 100 grams of tissue. On the clays of the kaolin type little or no change took place in the mineral composition of the plants. In all tests the results from the illite clays were intermediate to those of bentonite and kaolinite. In the above experiments, the bases included calcium, magnesium and potassium with calcium making up approximately three-fourths of the bases present in the soils. The clays were diluted to a cation exchange capacity of one to four m.e. per 100 grams with sand.

Eck, Drake and Steckel (1957) obtained results that were in some disagreement with those of other workers. In their research with tomatoes, they reported that at both 45 and 90 percent calcium saturation, kaolin is a better supplier of calcium than Wyoming bentonite. In this work there was no appreciable increase in calcium uptake until calcium saturation exceeded 75 percent. They went on to say that theoretically a montmorillonitic type colloid would require 90 percent or better calcium saturation before an appreciable quantity of calcium would be available. This paper recommended that calcium should be placed in limited soil area rather than in the entire soil area. This might conceivably raise the calcium saturation in this area into the desired range so more of it would be available to the plants. Another suggestion for increasing the availability of calcium was the heavy applications of potassium, magnesium or ammonium fertilizers in order to increase the base saturation with other ions to make calcium more available.

Benson and Toth (1963) grew tomato plants in sand-clay mixtures in order to determine the availability of calcium and potassium in the three types of clay. All of the sand-clay mixtures were brought up to 65 percent calcium saturation by adding calcium oxide. The magnesium was held constant in all treatments and potassium was the only variable other than the different clays. Potassium was varied from 3 to about 20 percent of the base saturation. The results showed that the best yields of tomato tops were obtained with the montmorillonite-sand mixtures, followed by kaolinite-sand and finally illite-sand mixtures. In all cases the best yield was with the higher potassium percentages. The mean uptake for calcium and potassium was also higher for the montmorillonite-sand mixtures. This is somewhat in contrast to the findings of the previous works reported, but in this case all of the treatments were in the range of 80 to 90 percent base saturation. As has been pointed out before, in this range most montmorillonite soils respond well to calcium and potassium.

Mehlich and Reed (1945) reported that on sandy loams at various levels of potassium and magnesium saturation the loss of these two ions is greater at the lower levels of calcium saturation than at the higher levels, when the levels of potassium and magnesium are the same at the two different levels of calcium.

Fleetwood (1925), in an experiment carried out in Missouri, stated that strongly acidic soils will respond to liming. A rule of thumb was presented as to the value of liming. It stated that if less than 600 pounds per acre were present in the soil, benefits probably would be gained by the addition of lime. On the other hand, if more than 600 pounds per acre were present, it probably would be of no great value as far as increasing yields of crops grown.

Naftel (1937) limed soils beyond the point of base saturation, which increased the soil reaction up to 75 percent. The readily soluble phosphorus was more than doubled in most cases by this addition of lime. Potassium was decreased by the addition of calcium carbonate and increased by the addition of calcium magnesium carbonate. This seems to indicate that the addition of magnesium with calcium will enhance the nutrient balance of the soil in more ways than to just add the ion.

Anderson, et al (1964) reported on the use of lime and rates of fertilizer application on the yield of strawberries in a two year experiment. During the first year of their experiment they found that the increased lime in the soil reduced the root growth of the strawberry plants. During the second year plants were planted in pots in April and at this time all lime and fertililizers were mixed in with the soil. The results indicated that there was no increase in the calcium content of the leaves through September, but by December there were large increases in the calcium content of the leaves according to the amount of lime applied.

A suggested explanation for the above reaction was that the roots of a strawberry plant must become well established before they are able to utilize any appreciable amounts of calcium from applied limestone.

Depending on the section of the country and the conditions prevailing, the use of lime in strawberries seems to be of questionable value. Gilmore (1959) worked with highly acid soils of recently cleared land in Tennessee. The original pH of these soils was 4.5 to 5.0. By increasing this up to 5.5 to 6.0, he obtained increases in yields from 25 to 44 percent. The experiment included four different levels of fertilizers along with the lime. At all levels the yield was increased by the addition of the lime.

Kirsch (1959) working with Olympic soils in Oregon reported that in some cases the yield of strawberries could be reduced by the addition of two to three tons of lime per acre. This amount of lime was broadcast over the entire field before planting. In conjunction with these liming experiments, fertilizers of various types were also applied to limed and unlimed fields. The results showed that the addition of potassium fertilizer and lime produced no increase in yield, and the lime and no fertilizer resulted in a reduced yield. This research was carried out in three different locations of differing natural fertility. On the fields that were naturally high in phosphorus and potassium no benefit was obtained with the addition of fertilizer and the yield was reduced by liming.

Chlorides

Chloride injury has been shown to occur on several crops, such as avocados, strawberries, citrus and others. Most of the experiments carried out are concerned with salt content of irrigation water while a few are concerned with the chlorides present in most potassium fertilizers.

Some of the chloride injury occurs in special cases, such as the work reported by Strong (1944). In Michigan, at that time, calcium chloride was being used on some gravel roads in an attempt to keep the dust down on the roads. Strong studied the trees growing beside these roads because they were becoming sick and dying. It was concluded that the calcium chloride that was washing off the road into the ditches was causing the damage to the trees. At this time the injury was attributed to the calcium chloride and not to chlorides as such.

Another case of chloride injury from rather unique sources was reported by Harper (1946). He studied the effect on pecan trees of the salt water pumped out of oil wells. The problem arose when the salt water began to seep through the soils and get into the water supply of the pecan trees. One of the problems encountered in this case was that the chlorides doing the damage were in the subsoil and a normal soil test failed to show them in the water. It was found that injury occurred when the chloride content of the soil reached 200 ppm. The first sign of injury is a tip burn of the leaf. It was also noted that leaves from areas of the tree losing the most water showed the worst injury and the first symptoms. These were the areas which were most exposed to the sun and wind.

Eaton (1942) conducted an experiment in an effort to prove or disprove the theory that there is a threshold level of chlorides in irrigation water beyond which injury will be obtained and below which no injury will be incurred. Plants were grown on chloride and sulfate salts at 50 and 150 m.e. chlorides and 50, 150 and 250 m.e. sulfate. Reduction in growth was obtained in all cases at the higher concentrations of both salts. In other experiments, it was concluded that, at lower concentrations, increasing increments of chlorides were more harmful than at the higher concentrations. That is to say at 50 m.e. chlorides one increment up will cause more damage than starting at 150 m.e. and adding the same amount of chloride. It was also stated that there is no threshold value for chloride concentration. It will build up in a soil, even at small concentrations, and cause problems with plants grown in that soil.

Siders and Young (1954) studied the effect of chlorides on pineapple. They grew plants in sand cultures at a constant chloride concentration and varied the concentration of nitrogen and potassium. The solutions contained three different treatments: (1) 39 ppm potassium and 28 ppm nitrogen, (2) 3.9 ppm potassium and 28 ppm nitrogen, and (3) 39 ppm potassium and 2.8 ppm nitrogen. The results showed treatment one to have the largest plants followed by treatment three and the smallest was treatment two. The chloride content per 100 grams of fresh weight was as follows: (1) 1.78 grams, (2) 3.73 grams, and (3) 4.23 grams. The terminal leaf necrosis, listed as the percent of dead to healthy tissue was (1) 0.33 percent, (2) 47.5 percent, and (3) 7.9 percent.

It was concluded from the above results that potassium seems to increase the tolerance of tissues to chlorides. Treatment two was a result of both chloride toxicity and a potassium deficiency.

In a separate experiment, fruit weight was studied in comparison to the various ions in the solution. The results showed that in cultures with ammonia nitrogen, the fruit weight was less. This was not the case in the nitrate nitrogen series. The chloride intake was also smaller in the nitrate nitrogen series.

Magistad, et al (1943) studied the effect of salt concentration and the kind of salt on the growth of alfalfa plants. Their results indicated that the chloride ions are more toxic to plants than the sulfate ions, but later they concluded that the osmotic pressure of the solution was more important than the ions present in the solution. The conclusion was also drawn that this will vary with the plant, therefore, the same statement cannot be used for all types of plants.

Maynard, Lachman and Gersten (1963) grew sweet corn plants in Hoagland's solution with a chloride content varying from 0.3 ppm to 300 ppm chloride supplied from sodium chloride. In this case no deficiency or toxicity symptoms showed up, and the plants at the two levels appeared uniform. In determining the chloride content of the plants from the two groups, it was found that the chloride content was uniform over the plant at the lower concentrations, while in the plants growing at the higher concentration the highest amounts were in the lower leaves and the lowest amounts in the upper leaves and grain. It appeared that the chlorides were selectively excluded from the reproductive plant fractions at high chloride levels.

Hewitt, Furr and Carpenter (1964) studied the effect of high concentrations of chlorides on different types of citrus cuttings in an eight week experiment. A group of citrus cuttings were watered with a one-third strength Hoagland's solution with 3640 ppm chloride. At the end of eight weeks the various plant components were analyzed for their chloride content. The leaves contained up to four percent chloride while the stems all contained less than two percent. The leaf content of chloride steadily increased over the entire eight weeks, while the roots had reached their peak content at the end of three weeks. There were symptoms of toxicity present during this time; tip burn, die back and some defoliation at the end of the eight weeks. The different varieties of citrus present showed symptoms according to their tolerance to the chloride ion.

Avocado growers have a great deal of difficulty with chloride toxicity in their crop, because most avocados are grown in the areas where the water contains large amounts of chlorides. Haas (1950) studied the effects of sodium chloride on three different types of avocados. The results showed that the top growth is retarded at 700 ppm and higher concentrations of the chloride ion. Roots on the other hand are retarded at 70 ppm chloride. It was also shown that the chloride content of the tissues increases with age but does not accumulate in the trunk.

Ayers (1950), also studied the effect of the chloride on avocados, but in this case the plants were grown in culture solutions. The findings indicated that the first tip burning will occur at around 0.6 percent chloride content in the leaves. Severe burning will be noted at one percent chloride in the leaves.

Haas and Brusca (1955) determined the amount of chlorides that avocados can stand in their nutrient solution before damage will begin to occur. They found that when the chloride content of the nutrient solution reached 442 ppm that tip burning occurred. With the chloride concentration at 709 ppm, it was found that ammonium phosphate would help to minimize the injury.

The ammonium ion was added to the solutions at 111 ppm as ammonium nitrate, ammonium sulfate and as ammonium phosphate.

All three reduced the chloride injury, but the phosphate was the best in reducing the damage done by the chloride.

Kadman (1963) reported on studies carried out to determine the tolerance of avocado seedlings to saline conditions. As others have reported, the more severe the leaf scorch the more chlorides are present in the leaves showing the damage. The work reported was carried out by irrigating avocado seedlings with a nutrient solution containing 500 ppm of the chloride ion. The first symptom to show is a marginal chlorosis much like a potassium deficiency. This is followed later by a marginal necrosis. Eventually the entire leaf will die and fall off. A difference in the tolerance of varieties was also reported.

Hayward and Long (1942) grew several different peach rootstocks at varying concentrations of chlorides and sulfates. The chloride concentrations varied from 36 to 2846 ppm and the sulfate concentrations were 3842 and 7684 ppm. These trees were grown for one year at a lower concentration in order to get them established before such severe treatments were begun.

During the first year the young trees were grown in the high concentrations of chloride, eight out of twelve died. Two of these were replaced with healthy trees and all of these trees survived the first year, but died during the second year of their growth. The trees at the high sulfate showed no symptoms, but the growth was markedly reduced over the checks. There was also no mortality at the high sulfate levels. The intermediate levels of chlorides showed the normal symptoms of chloride injury and also had reduced growth. The trunk increase in both the high and the low chlorides was considerably less than that of the checks. The trunk increase of the intermediate sulfate treatment was also reduced but not to the extent of the intermediate chloride treatments. This research tended to indicate that for peaches the chloride ion was more detrimental than the sulfate ion.

Brown, Wadleigh and Hayward (1953) determined the effect of sodium chloride, calcium chloride and sodium sulfate on almonds, peaches, apricots, plums, and prunes. The results of varying amounts of these elements, indicated that for these plants the specific ions were more important than the osmotic concentration of the solution. At two atmospheres pressure of calcium chloride, all of the trees except apricot died in their second year of growth. All of the other treatments lived for the full three years of the experiment. The other treatments included two atmospheres osmotic pressure of the other two compounds listed above. The difference in damage between calcium chloride and sodium chloride was attributed to the calcium ion facilitating the entry of the chloride into the plant resulting in greater injury.

Parups, et al (1958) studied the growth and composition of leaves and roots of Montmorency cherry trees in relation to the sulfate and chloride supply. The chloride concentration varied from 0 to 671 ppm and the sulfate varied from 0 to 672 ppm. No injury was obtained with chloride concentrations up to 247 ppm, but significant decreases in growth occurred when the chloride content of the nutrient solution was increased above this value. At 0 ppm sulfate a sulfur deficiency was noted, but if chlorides were present in the solution this did not show up. It was also noted that when a high sulfate treatment was combined with a high chloride treatment, the sulfate seemed to overcome the detrimental effects of the chlorides. High levels of both of the ions reduced the growth of these cherry trees. The increase of chloride in the solution tended to decrease the potassium content of the plant but had little effect on calcium or magnesium. High sulfate seemed to have the opposite effect, but this was not a significant change in the content of these ions.

Dilley, et al (1958) studied the effect of chloride and sulfate ions on apple, cherry, peach and grape plants. The concentrations used were 0, 355 and 655 ppm chloride and 192, 384 and 624 ppm sulfate. The effect of the high chlorides was evident after the first month. The apple was the most sensitive, and the peach the least affected by the chlorides present in the nutrient solutions. A leaf symptom appeared on the peaches receiving the high chlorides. This symptom manifested itself as a chlorosis developing first at the base of the leaf and spreading upward. As reported in the previous article, those plants receiving both high chlorides and high sulfates did not show the symptoms of chloride injury. Leaf analysis indicated that the sulfate inhibited the uptake of chloride and the chloride also inhibited the uptake of excess sulfates.

Ballinger (1962) conducted a survey in North Carolina to determine if any damage was being done to blueberries by the use of potassium chloride fertilizers. Before carrying out this survey it was necessary to grow blueberry plants in the greenhouse and determine the minimum amount of chlorides the plants could possess in their leaves and still not be in any danger. This study determined that the blueberry could withstand 0.5 percent chlorides in their leaves. The plants were grown for five months in 104 m.e. of chloride and only a slight amount of burning of the leaves was observed. The survey of blueberries from around the state revealed that the maximum amount of chlorides found at any location was 0.14 percent and minimum was 0.02 percent with the average at 0.07 percent. This indicated that there was no danger from the chlorides used in the fertilizers since the plants could tolerate up to 0.5 percent chloride before damage occurred. The recommendation of this paper was to continue using the chloride anion for potassium fertilizers since potassium sulfate and nitrate are more expensive than potassium chloride.

The effect of chlorides, mostly in irrigation water, on strawberries has been studied by several different workers. Ehlig and Bernstein (1958) determined the tolerance of strawberries to salts. The strawberry plants used were allowed to become established for one month before any of the salts were added to them. After one month, sodium chloride, calcium chloride and sodium sulfate were added to give one and two atmospheres of chlorides and two atmospheres of sodium in the sulfate form. The plants in the sand cultures showed damage three days after the addition of the salts. This damage was in the form of burned tips on the small leaves as they were emerging from the bud. The burn occurred at 40 m.e. of chloride per 100 grams of dry leaf tissue. The plants grown at the high sulfate levels also showed injury, but this required two months before it showed up. In these experiments, the top growth was more influenced by the high chlorides than were the roots. In a separate field experiment, Ehlig and Bernstein determined the effect of high salts on the yield of strawberries. The results indicated that when the conductivity of saturation extracts reached 2.3 to 2.6 mmhos that the yields of marketable fruit can be decreased by as much as 50 percent. If the conductivity of the saturation extract reached 3.0 to 3.6 mmhos the plants all died the next spring when growth should have resumed.

Van Dam (1955) studied the ability of various types of plants to grow in the soils of Holland after they were flooded by salt water in 1953. This report stated that strawberries, particularly young plants trying to become established for the first time, are very sensitive to chlorides in the soil and were not recommended to be planted in these soils.

Brown and Voth (1955) studied the effects of so called pure water, which had a small amount of dissolved salts in it, on the growth of strawberries in California fields. The results showed that the cultural practices necessary for strawberry production can cause salt accumulation, with resulting injury to the plants, in some areas where the irrigation water is considered to be of good quality for most crops. This research was carried out to determine whether sprinkler or furrow irrigation is better for strawberries under California conditions. Due to the accumulation of salts in the furrows following furrow irrigation, it was stated that sprinkler irrigation is better if the concentration of sodium and chloride exceeds 100 ppm. The symptoms of this salt damage, is first evident in young plantings. Runners on plants in high salt areas are short and thickened with practically no fine root formation. During the second year, plants, which have not been visibly affected in the first year, root deeper and can apparently stand a higher salt concentration.

Ljones and Refsdal (1954) conducted both field and greenhouse trials in which they determined the effect of the carrier anion for potassium on strawberries. They applied varying rates of potassium chloride, potassium sulfate and potassium-magnesium oxide. They found that in the field trials that the two highest levels of potassium chloride caused chloride injury to the plants. In the greenhouse trials, two different varieties of strawberries were grown in pots and were watered with water containing from 0 to 0.4 percent chloride as potassium chloride, sodium chloride and calcium chloride. Damage was severe in all cases at the higher concentrations of chloride, but was most severe when the chloride was supplied as potassium chloride. Leaf symptoms did not appear until the leaf content reached 0.4 percent chlorides on a dry weight basis.

Ehlig (1961) also studied the effects of chlorides in the irrigation water on the subsequent growth of strawberries. He grew Shasta and Lassen varieties in sand cultures. These plants were given 10 m.e. of chlorides per liter of nutrient solution as either calcium chloride or as sodium chloride. Some plants were also sprinkled with solutions containing like amounts of chlorides. These plants showed no adverse effects to this treatment. The plants growing in the nutrient cultures were taken out after 46 days and tested for their chloride content. The Shasta variety had accumulated injurious amounts of chlorides which was characterized by a progressive necrosis advancing from the leaf margins inward. This variety had accumulated 60.9 m.e. chloride per 100 grams on a dry weight basis from the calcium chloride and 53.6 m.e. chloride per 100 grams dry weight from the sodium chloride. Lassen did not show the adverse effects of chloride and no marginal necrosis was present. This variety had accumulated 24.9 and 22.1 m.e. chloride per 100 grams of dry tissue from calcium chloride and sodium chloride. The chloride content of the tissue can go as high as 35 m.e. per 100 grams before symptoms of injury will appear. The sodium from the sodium chloride did not seem to have any adverse effect on the plants according to the results of this experiment.

Bernstein (1965) reported that the damage to fruit crops by excessive salts could be classified into two groups: (1) those that are not affected by any one salt in particular, but are sensitive to a high osmotic pressure, and (2) those that are more adversely affected by a specific ion rather than a specific osmotic pressure. Strawberries belong in the first group mentioned because they are sensitive to all salts at given osmotic concentrations, and grapes belong to the second group because they are more sensitive to a given concentration of chlorides than to the same concentration of other salts. In this report strawberries are said to be very sensitive to salts in the soil. The upper limits that a very sensitive variety can stand is reported as five m.e. per liter of chlorides in the soil extract. It was also stated that a ten percent reduction in yield occurs when the electrical conductivity of the saturation extract reaches 1.5 mmhos per centimeter.

The general statement is made that if tip or marginal leaf burn occurs in a crop and the leaf content of chlorides is 0.5 percent or above, then chlorides are probably causing the damage to the plant. It was pointed out that this type of damage was most likely to be seen in hot, dry weather rather than during cool, cloudy weather. The frequency of irrigation also affects the amount of damage that a given amount of salts in the soil will cause. If the soil is kept moist, there is less likely to be damage because the salts that are in the soil will remain in their most diluted form.

Dalton (1963) reported that the salt damage that was occurring to strawberries in Dade County, Florida was due to the salts that were being added in the fertilizers rather than by salt intrusion from the ocean. In this experiment chlorides were found in concentrations of up to 1000 ppm in a field that had had 3500 pounds per acre of a 4-8-8 fertilizer applied to it. There was a complete loss of the plants in this field. The mmhos conductivity reading on this field was 3.0 mmhos per centimeter, which is in agreement with the results of Ehlig and Bernstein (1958).

The Southwest Potash Institute (1965) has reported that with the use of potassium nitrate, it is possible to reduce the salt index of the fertilizer and at the same time to eliminate the presence of the chloride or sulfate ions which may be harmful to plants. In the same paper, they stated that in work carried out in Florida potassium nitrate had increased the yield of strawberries in some cases when compared to potassium chloride.

MATERIALS AND METHODS

Base Saturation

All plants of _Fragaria ananassa_, Bailey used in this experiment, with the exception of those specifically mentioned, were of the Northwest variety. This variety was chosen for use because it is the most widely grown variety in Oregon. The research presented was set up in an attempt to determine the effects of increasing the base saturation on the yield of commercial strawberries.

This investigation was carried out in commercial plantings of strawberries located throughout the state. Originally plots were set up at six different locations, but due to the winter freeze of 1965, one field at Lafayette was lost, while a second field located at Hood River, was taken out of production because of red stele - a fungus disease which attacks the roots of the plants.

This work was begun in the summer of 1964, and all fields chosen belonged to growers who had placed in the 5-50 Ton Club for the previous year. This is a grower organization that recognizes the better growers by giving them membership in the club. To become a member, it is necessary to raise five tons of berries per acre on ten acres or 50 tons of berries on fewer acres.

These growers were chosen because their yields were good, and approximately the same, but the percentage base saturation of their soils varied somewhat from grower to grower. Some of these were at levels that could be considered as low. In each location a first year field was chosen. The term "first" year field refers to the fact that it is in its first year of production. These fields would therefore have been planted in the spring of 1963 and the first crop was in 1964. Normally Oregon strawberry fields will yield for at least three seasons. Therefore, in choosing this age of plants, it was hoped that the experiment could be followed for a two or three year period.

The loss of the two plantings left only four plantings in a condition from which yield data could be taken. These were located at McMinnville, Salem, Buxton and Hood River. The field at Hood River was the only one that did not consist entirely of the Northwest variety. It was half Northwest and half Marshall. In this field the treatments were split between these two varieties in an effort to determine whether there was any difference between the two varieties in their response to the increased base levels.

Between the dates of June 24 and June 30, 1964, plots were set up in each of the fields. These plots were paired in an effort to reduce the variability of the different portions of the fields. Five of these paired plots were set up in each of the fields. This was done by staking out 25 foot sections of a row in two different rows with two to four buffer rows in between them.

The plots were marked by driving 12 inch white stakes into the ground at each end of the plot to clearly show the boundaries. A map was drawn of each of the fields giving the locations of each of the plots and their distance from a reference point so they could be found again in case any of the stakes were removed. At this time a soil sample was taken to determine the original level of all the bases present in the soils of the different areas so it could be determined how much of each element was needed to bring them up to the levels decided on for the tests.

The soil samples were taken with a soil testing tube to a depth of six inches. The samples were combined in each field so as to provide two different soil samples of five cores each for the treated plots and the check plots. Samples were taken between the rows and in the rows between the plants. This gave four soil samples for each field. The samples were combined in such a manner that they could be identified and duplicated in subsequent samplings.

A second set of samples was taken from each of the plots between July 27 and July 29, 1964. The primary purpose of this sampling was to get a sample to compare with the original one before any materials were put on the fields. All of the soil samples were analyzed by the Soil Testing Laboratory of Oregon State University. There were no significant differences in the two sampling data so the results are combined.

Table 1. Original fertility levels of the four soils used in m. e. per 100 grams of dry soil.

Location	C. E. C.	Ca	Mg	K	Total % B. S. Inc. Na
Hood River	17.4	2.15	0.5	0.23	17.2
Salem	25.95	4.4	0.9	0.81	24.0
Buxton	18.36	3.85	0.98	0.54	30.3
McMinnville	15.45	5.56	1.50	0.58	50.4

From the data given in Table 1, an attempt was made to determine the amount of calcium, magnesium and potassium which would be needed in each field in order to increase the base saturation to a level considered likely to improve yield. An attempt was made to increase each base proportionally rather than add a large amount of just one element, such as lime, and possibly throwing off the "balance" of the bases. By this it is meant that if a large amount of any one base were added and no others it is possible that this one base would displace a large amount of other bases from the exchange complex of the soil, and they would thereby be lost through leaching.

The materials used in this work were ground limestone to increase the calcium, magnesium sulfate for the magnesium, and potassium chloride for the potassium. The preceding materials were chosen because they are commonly used in commercial fertilizing programs. An extended effort to find another form of potassium was not made when it was found that only the chloride form could be obtained in Corvallis.

The fields were not all increased to the 80 percent level of base saturation which seems to be the best for the montmorillonite clays for two reasons: (1) the high cost that would result from a grower having to add this amount of materials to a field, and (2) putting this amount of the readily soluble materials into the soil might cause trouble due to high salts.

The field at Hood River was increased from its original level of 17.2 percent base saturation to 45 percent base saturation. The planting at Salem was increased from 24 to 45 percent base saturation, the one at Buxton from 30.3 to 50 percent and the one at McMinnville from 50.4 to 60 percent base saturation. The amounts of each of the materials added to each of the plantings are given in Table 2.

The m.e. of each one of the materials listed previously were converted into the tons per acre that would be necessary to add to an acre. These figures were then converted into the amounts that would be required to bring a 25 foot section of row up to this level. These figures were based on the fact that 1,111 pounds of ground limestone are necessary to increase the level of calcium one m.e. in an acre of soil; 2,961 pounds of magnesium sulfate are required to increase the level of magnesium by a like amount and 156 pounds of 60 percent potassium chloride is necessary to increase the

the potassium in an acre of soil by 0.1 m. e. The materials were applied to the rows in bands along each side of the row as evenly as possible. In all cases the materials were added to one of the paired plots and to the remaining one nothing was added. This row served as a check to determine whether any difference in yields could be found between the treated plots and those that had not been treated. All of the treatments were applied in the middle of September.

Table 2. Millequivalents of materials added to each planting in order to increase the percentage base saturation.

Location	Ca		Mg		K	
	added	total	added	total	added	total
Hood River	3.25	5.40	1.30	1.80	0.37	0.60
Salem	3.50	7.90	1.80	2.70	0.10	1.00
Buxton	2.25	6.10	1.12	2.10	0.26	0.80
McMinnville	0.64	6.20	0.60	2.10	0.22	0.80

In June of 1965 all of the fields were harvested during the time commercial berries were being picked in the area. It was not possible to pick them as often as would be done commercially because of the great distances between the different plantings. During the harvest season each of the plantings were harvested at least once a week. Most of the time one planting was picked twice in the week since there were only four fields. The longer times between pickings resulted in more overripe berries than normal. No attempt was made to determine whether there were differences in time of ripening between the treatments and the checks. All of the berries were harvested and brought into the laboratory to be weighed.

In April and at the end of the picking season, leaf samples were taken from each field and analyzed for calcium, potassium, magnesium and phosphorus to determine if the added minerals had any effect on the mineral content of the leaves of the plants.

The leaf samples were collected from within the 25 feet confines of the plots and a 20 leaf sample was taken from each plot. These samples were combined in the same manner as the soil samples, giving a composite sample of 100 leaves for each five plots. All leaves taken were of the most recently matured growth, in an attempt to obtain some degree of uniformity within the sampling technique.

The leaf samples were brought into the lab and washed and dried. Prior to being ground the petioles were separated from the rest of the leaf in order to analyze them separately. This was done because the mineral content of the different parts of the plant have varying concentrations of the mineral constituents and most of the work reported in the literature gives the concentrations for both the leaf blades and the petioles. The samples were prepared according to the method of Chapman and Pratt (1961).

After washing, the leaves were placed in a tunnel dryer and dried for 24 hours at 65^{o} C. Once the samples were completely dry, they were ground in a Wiley mill. After grinding the samples, one gram of each was weighed and ashed. The samples were ashed in an electric muffle furnace at 200^{o} C for two hours, then 400^{o} C for two hours and finally at 550^{o} C for six to eight hours.

After cooling, the ashed samples were taken up in 10 ml hydrochloric acid (1+4) and baked to dryness. The samples thus prepared were then taken up into 0.1N hydrochloric acid and filtered through Whatman #2 filter paper. This was then brought up to a 100 ml volume. From this stock solution the determinations for calcium, magnesium, potassium and phosphorus were made.

The determinations of calcium and potassium were made by taking the solution prepared by the above method and diluting it ten times. This solution was then ready for analysis with the Beckman Model DU Flame Spectrophotometer. For the determination of calcium the slit width was set at 0.011 mm; the wavelength was set for 5540 angstroms and the gases used were oxygen and acetelyne. These gases were also used for the determination of potassium but with a slit-width of 0.1 mm and a wavelength of 7665 Angstroms.

Magnesium was determined on the same machine, but with a different solution. For the magnesium determination the standard solution was diluted differently. For this determination 20 ml of the stock solution was used and five ml of 95 percent ethanol added. This solution was then used in the flame for magnesium determination. The flame was changed by substituting hydrogen gas for the acetylene. The slit width used was 0.057 mm and the wavelength 2850 angstroms.

For all three of the previous elements discussed, the flame was set up first using standards to obtain a standard curve for determining the amount of the particular element in the sample. This was done by setting the flame at 0 transmission for distilled water and 100 percent for the desired upper limit for that element. In this manner all readings between the two indicate a specific amount of that particular element.

To determine the amount of phosphorus in the sample, a two ml aliquot of the ash solution was used. This was placed into a 50 ml volumetric flask and four ml of molybdate reagent was added. Molybdate reagent consists of 25 grams of ammonium molybdate in 600 ml of 10 N sulfuric acid diluted to one liter. This solution was allowed to stand for 10 to 15 minutes before the second reagent was added. At the end of this period 30 to 40 ml of water was added to each flask, then two ml of amino-naphthol-sulfonic acid was added to each one. This mixture was then diluted to 50 ml and allowed to stand 60 minutes and then read in a colorimeter. In this determination, time is very critical and large diviations from the times indicated will cause failures in the procedures. The colorimeter used in this part was a Bausch and Lomb set to read for absorption at 650 mu. A red filter was used in conjunction with the 1P4d photo tube.

Chlorides

The research to determine the effect of the chloride ion on strawberry was conducted in three parts: the first two consisted of greenhouse problems and the third consisted of taking samples from commercial plantings in the state and analysing them for their chloride content.

The method used for the determination of the percentage chloride in the plant parts was a combination of that of Brown and Jackson (1955) and the procedure given for determining the amount of chloride in a water sample without titrating, using a Beckman Silver Electrode (Beckman Instruments, Inc., 1962). Brown and Jackson's method consists of drying and grinding the samples and then wet ashing them overnight in 0.1 N nitric acid. Once the samples have been ashed overnight, they are titrated with 0.1 N silver nitrate using a pH meter with a silver electrode instead of the saturated potassium chloride electrode normally used for the determination of pH. In this method the meter is set at a convenient spot, usually around -100 mv, and the solution containing the chloride is titrated until the needle takes a violent swing toward this number.

The manufactures of the electrode give a method for the determination of the amount of chloride present in a water sample. This method involves the coating of the electrode with silver chloride and the direct measurement of the chloride ion by the mv potential between the two electrodes. The electrode is coated with silver chloride by an electrolytic action. This is done by placing it in a saturated potassium chloride solution connected to a one and one-half volt battery with a silver wire acting as the other pole. After the electrode is coated in this manner, a standard curve is determined for the different concentrations of the chloride ion. Since a change of 59 mv equals a ten-fold change in the chloride concentration, this will give a straight line curve if plotted on semi-log paper. Samples can then be read for their mv potentials and the value of the chloride, in ppm, can be read directly from the chart.

The method used in this work was a combination of the above two; the latter was not sensitive enough for the low concentrations found in plant samples, so the titration method had to be used. The two methods were combined in that a coated electrode was used in the titration method. In this manner the approximate concentration of the chloride was known before the titration method was begun, and therefore the approximate amount of the silver nitrate needed was known. Another modification in the titration method that was incorporated into this procedure was the use of a one gram sample when wet ashing instead of the one-half gram called for. This gave more of the chloride ion in the sample and, therefore increased the amount of silver nitrate necessary for the titrations. This was considered by the author to be better because the amount of chloride that is present in a one-half gram sample, even at concentrations thought to be damaging, require a very small amount of the silver nitrate to neutralize it.

In order to use the modified method of titration discussed above, it is necessary to make the standard solutions for the standard curve with the 0.1 N nitric acid which the samples are digested in over-night. If this is not done, the readings obtained will be slightly different since the acid changes the solubility of the silver chloride in the solution. As long as the acid is added to the stock solutions, it is possible to be fairly sure of the amount of the 0.1 N silver nitrate which will be necessary to take all of the chloride out of the solution.

All samples were analyzed by the method described above. The samples were brought into the laboratory, washed, dried and ground in the manner described in the previous section on base satur-ation. One gram samples were weighed out into 250 ml beakers and ten ml of 1.0 N nitric acid added to each. Once the material in the beaker had become thoroughly wet, 90 ml of water was added to the beaker to make the 0.1 N acid. The 1.0 N nitric was used to begin with because the leaf tissue is difficult to get wet by the diluted acid. When the 1.0 N acid is used it is possible to have all the tissue wet and digestion started in a few minutes if agitation is employed. Following the wet digestion, analysis was made using the procedure described previously.

The leaves picked in the various fields that were chosen for the survey were of a slightly different age than those picked for the base saturation research. The leaves used in this work were of the older growth, since the chloride concentration is variable and is more concentrated in the older leaves. It was thought that the leaves from those areas where there is most likely to be trouble should be taken for analysis. Attempts were made to visit areas where problems with chloride toxicity might be encountered. This was determined by symptoms seen in the fields which were similar to those described in the literature for chloride toxicity. That is, marginal necrosis of the leaves and poor growth of young plants.

The two greenhouse experiments were carried out at Corvallis, Oregon. Both were designed to determine whether there actually was damage to the Northwest variety by chloride and to determine how much chloride the plants could tolerate.

The first experiment was set up to determine whether young strawberry plants were damaged by fairly low concentrations of chloride. To determine this, young strawberry plants, all weighing between six and eight grams, were planted in crocks filled with sand. Each crock had a single hole in the bottom.

A rubber stopper fitted with glass tubing was inserted into the bottom of each crock. Rubber tubing was used to connect the crock to an 18 liter glass bottle containing the nutrient solution.

Each 18 liter bottle was fitted with a two or three hole rubber stopper with glass tubing inserted into the holes. One glass tube was connected by a rubber tubing linkage to a pressure regulated air supply switched by a timing interval device. The other tubes reached to the bottom of the nutrient supply bottle and the upper outlet end was connected by tubing to the glass tube insert at the base of a crock as mentioned. This system permitted alternate pumping and draining of the solution through the sand in the crocks. Each bottle contained either a standard Hoagland's #2 nutrient solution (Hoagland and Arnon, 1950), or, in addition to this, some bottles had varying amounts of both chloride and sulfate ions in them. These ions were supplied by either hydrochloric or sulfuric acids. The acids were used to avoid the introduction of another variable, such as sodium.

There were three rows of crocks in the benches and only two rows of jugs, so this made it necessary to have two crocks on half of the jugs and only one on the other half. With the exception of the necessity of having the same treatment on the same jug, the treatments were all completely randomized. The bench contained 57 crocks, but to make an even number of treatments, only 56 of these were used.

The experiment was set up as two separate ones instead of a single combined one. That is, one testing the effect of the chloride ion and the other the effect of the sulfate ion. There were no treatments which included both ions. One part of this experiment included the addition of the sulfate ion to the solution at the rates of 384 ppm, 576 ppm, and 768 ppm. The standard Hoagland's solution contains 192 ppm of sulfate. Adjustments of sulfate were made by the addition of 4 N sulfuric acid. This concentration was chosen because of the ease which this made the addition of the material. For example, 192 ppm is one ml of 4.0 N sulfuric acid in one liter of water or other solution.

The chloride part of the experiment included concentrations at 0, 248, 496 and 992 ppm chloride. These concentrations were obtained by the addition of 7 N hydrochloric acid to the nutrient solution. This concentration was also used for the convenience of being able to add one unit of chloride (248 ppm) to one liter in one ml. The original intent of the experiment was to continue these plants in the crocks for two months, but the results indicated that these concentrations were too high, especially for young transplants. Therefore, they were taken out at the end of a two week period on July 28, 1965.

The second greenhouse trial was conducted from August 16, 1965 to October 17, 1965. This trial utilized older plants instead of the young transplants used in the first trial. It was decided to use older plants for this experiment because Brown and Voth (1955) reported that mature plants could withstand higher concentrations of chloride and this trial was set up to determine whether this was true. The plants used in this work were Northwest variety originally selected for uniformity in size and weight. These had been growing in the greenhouse in cans for one year. These plants had received no previous treatment other than a routine fertilization with Rapid Gro solution just sufficient for good growth.

These one year old plants were removed from the cans in which they were growing, reselected for uniformity, and replanted in crocks containing sand. All the dead leaves and fruit clusters were removed prior to transplanting. The plants were grown in the crocks for a two week period prior to any treatment, in order to allow them to overcome any shock of transplanting.

At the end of the two week waiting period, 48 plants were selected for uniformity. The trial was set up as a factorial experiment involving both sulfate and the chloride ion. There were four levels of the chloride ion and three levels of the sulfate ion, counting the basic level of 192 ppm sulfate in a Hoagland's solution.

The levels of chloride used were 0, 62.5, 125 and 250 ppm and the levels of sulfate were 192, 384 and 576 ppm. The nutrient solutions used in this trial were made up in the same manner as the ones used in the first greenhouse trial. The 18 liter bottles were kept filled to approximately the full mark in order to prevent loss of water from the solutions and the subsequent increase in the osmotic pressure. The solutions were changed in all the bottles on the 16th of September.

The nutrient solutions for both of the experiments described above were pumped up into the crocks and allowed to drain back into the same bottles by gravity according to the system previously described.

The time mechanism was set up in such a manner that two clocks were utilized, one a percentage timer which regulated the percentage of time each hour that the air pump was on, and the second was a 24 hour clock that controlled the times of day that the percentage timer operated. The percentage timer was hooked directly to the solenoid valve. When it was on, the solenoid valve allowed air to be pumped from the pressurized system into the air lines that pumped the air pressure up into the bottles which caused the nutrient solution to be forced up into the crocks with the plants.

When the percentage timer shut off, the solenoid valve opened up allowing the air that was trapped in the system to be drained off and thereby allowing the solution to drain back into the bottles. The 24 hour clock regulated the time of day that the percentage timer was allowed to operate. Without this clock the nutrient solution would have been pumped up into the crocks every hour.

When the plants were first transplanted into the sand from the soil in which they had been growing, they had to be watered much more frequently than after they had become established in the crocks. At first it was usually necessary to have them watered every hour through the daylight hours, but once they had become established they required watering only twice a day. The percentage timer was set in such a manner that it allowed the system to be pressurized only until the solution broke the surface of the sand and then it turned off. Since not all the crocks filled up at the same time, it was necessary to set the timer in such a manner that the plants in all the crocks would receive enough water and nutrients. The reason for not allowing the plants to be watered every hour, was not due to fear of over watering but to prevent algae from growing over the moistened sand surface.

To prevent algae growth in the tubes that carried the nutrient solutions to and from the crocks, black rubber tubing was used on all the lines. In this manner no light could penetrate the tubing and, therefore, no algae would grow in them. All of the bottles that contained the solutions were painted to prevent light from getting inside and allowing algae growth in them.

On the 18th of October, all of the plants were taken from the crocks to be analyzed for their chloride and other mineral content. At this time the leaves were ground after washing and drying in the manner described previously. The leaves were analyzed for potassium, calcium, magnesium and phosphorus with a Perkins-Elmer 303 Atomic Absorption Spectrophotometer. The samples were handled as previously described for the base saturation study through the taking up in a 0.1 N hydrochloric acid. A two ml aliquot of each sample solution was diluted up to 100 ml after adding 3 ml of strontium chloride. This system was used for all three determinations.

RESULTS AND DISCUSSION

Base Saturation

The data from the analyses of the leaf samples taken in April, 1965 are presented in Table 3 and those for the July, 1965 sampling are presented in Table 4. As can be seen in these tables, there were no consistant differences in the mineral content of leaves of the treated plants over those of the untreated plants for the April sampling. The July sampling gave an indication of an increase in the magnesium content of the treated leaves and petioles over the nontreated plants. This difference in the magnesium content of the leaves is the only indication that any of the applied elements had an effect on the mineral content of the leaves.

The results of the soil samples taken at the time of the last leaf sampling are presented in Table 5. The calcium and magnesium content of the soils was increased over that of the nontreated soils, but the potassium level was not increased. The apparent lack of increase in mineral content in the McMinnville plots might be explained in one of two ways. First, since the materials were banded in, it is possible that when the samples were taken they were not taken in the region where the elements had penetrated, or secondly, they had all been leached out of the soil by the winter rains.

Table 3. Mineral content of strawberry leaves seven months after the application of calcium, magnesium and potassium.

Location	calcium		magnesium		potassium		phosphorus	
	treated	control	treated	control	treated	control	treated	control
Hood River								
leaf - NW	0.92*	3.52	.191	.145	2.63	0.76	.191	.24
petiole	1.09	1.00	.182	.176	0.59	0.63	.26	.21
leaf - Mar	0.95	1.10	.248	.232	0.83	0.92	.22	.28
petiole	2.83	2.45	.242	.275	0.88	1.07	.26	.185
Salem								
leaf	0.53	1.27	.145	.160	1.42	1.59	.26	.135
petiole	0.48	0.76	.125	.132	3.30	2.97	.18	.143
Buxton								
leaf	0.55	0.76	.225	.216	1.22	1.51	.325	.290
petiole	0.76	0.65	.191	.182	3.72	3.57	.23	.24
McMinnville								
leaf	0.43	0.43	.145	.152	1.42	1.16	.313	.335
petiole	0.43	0.80	.132	.198	3.25	2.26	.24	.23

* percent of the element in the leaf material on a dry weight basis

Table 4. Mineral content of strawberry leaves ten months after the application of calcium, magnesium and potassium.

Location	calcium		magnesium		potassium		phosphorus	
	treated	control	treated	control	treated	control	treated	control
Hood River								
leaf - NW	1.37*	1.30	.335	.323	1.01	0.89	.143	.163
petiole	1.23	1.23	.323	.275	0.79	0.84	.085	.118
leaf - Mar	1.27	1.00	.300	.198	1.00	0.88	.180	.180
petiole	1.08	0.80	.244	.210	1.07	0.88	.260	.163
Salem								
leaf	0.88	0.76	.175	.160	1.42	1.44	.208	.240
petiole	1.23	0.92	.182	.166	2.22	2.56	.150	.163
Buxton								
leaf	0.92	0.92	.198	.167	1.16	1.11	.250	.200
petiole	0.65	0.76	.132	.133	1.51	1.32	.163	.150
McMinnville								
leaf	1.00	1.43	.207	.191	0.98	1.31	.180	.190
petiole	1.23	0.68	.175	.145	1.35	1.51	.250	.250

* percent of the element in the leaf material on a dry weight basis

Table 5. Nutrient level of soils ten months after the addition of calcium, magnesium and potassium.

Location	calcium*		magnesium		potassium		phosphorus		T.S. (mmhos per cm)	
	treated	control	treated	control	treated	control	treated	control	treated	control
Hood River										
In Row	5.4	2.4	1.0	0.7	.40	.38	30.5	29.0	.30	.18
Between Row	5.2	2.8	1.5	0.9	.93	.30	26.0	25.0	.50	.26
Salem										
In Row	5.0	4.5	0.9	0.9	.62	.65	13.5	12.5	.50	.35
Between Row	8.5	3.2	1.3	0.9	.83	.79	14.5	13.0	.63	.50
Buxton										
In Row	4.5	3.4	1.5	1.2	.74	.79	27.5	25.0	.16	.15
Between Row	5.4	4.3	1.6	1.3	.77	.69	22.0	20.5	.26	.18
McMinnville										
In Row	5.6	5.4	1.5	1.5	.69	.69	54.0	53.0	.18	.20
Between Row	5.4	5.4	1.8	1.6	.79	.77	48.0	50.5	.72	.42

* Calcium, potassium and magnesium are given in m.e. per 100 gms of soil.

In view of Bernstein's work (1965) on the effect of high salt concentrations on the yield of strawberries, it is significant to point out the differences in the total salts for the treated and the untreated soils. As can be seen from Table 5, the total salts are higher in all treated soils than in those controls that received only their normal fertilizer.

Table 6 presents the yield data from the various plantings involved in this research. The yields are presented in the order of increasing original soil base saturation.

Table 6. Yield data of 1964-1965 nutrition studies on strawberries.

Location	Treated Plots	Checks	Difference
Hood River*	59.86 kgms	58.06 kgms	+1.80 kgms
Salem	71.61 kgms	71.93 kgms	-0.62 kgms
Buxton	34.45 kgms	36.24 kgms	-1.79 kgms
McMinnville	82.99 kgms	85.81 kgms	-2.82 kgms

* Both Northwest and Marshall strawberries are added since no differences between the two varieties was noted in the yield.

The data in Table 6 indicate a definite pattern in the yields of the various plantings, showing an initial increase in yield due to the addition of bases at the lowest base saturation and changing to a decrease of more and more as the original percent base saturation increased.

The curve produced by plotting the original percent base saturation as the abscissa and the change in yield as the ordinate lends itself to evaluation by curvilinear regression. See Figure 1. When the values in this figure are tested, using curvilinear regression, an r value of 0.9985 is obtained. An r value of this amount indicates a very close fit to the curve, since an r value of one indicates that it is a perfect fit. When this r value is tested for significance using the F test, it is found that the value obtained is significant at the five percent level. This significance shows that the responses of the different fields are not the same, but that the influence of increased base saturation on the yield of strawberries is dependent on the original base saturation.

The effects on the yield of strawberries presented in Table 6 are those obtained when the bases are applied to fields with established strawberry plants already growing. The findings presented may not apply to the addition of bases to the field in advance of the planting of the strawberry plants.

The findings of this research agree to some extent with those of Kirsch (1959) who reports that the liming of strawberries can decrease yields. This work goes further in that it includes leaf and soil analysis, before and after application of the bases, along with yield data in an effort to determine the reason for this phenomenon. The data in Table 6 seems to indicate that if the percentage base saturation is very low, below 20 percent, the yield will not be

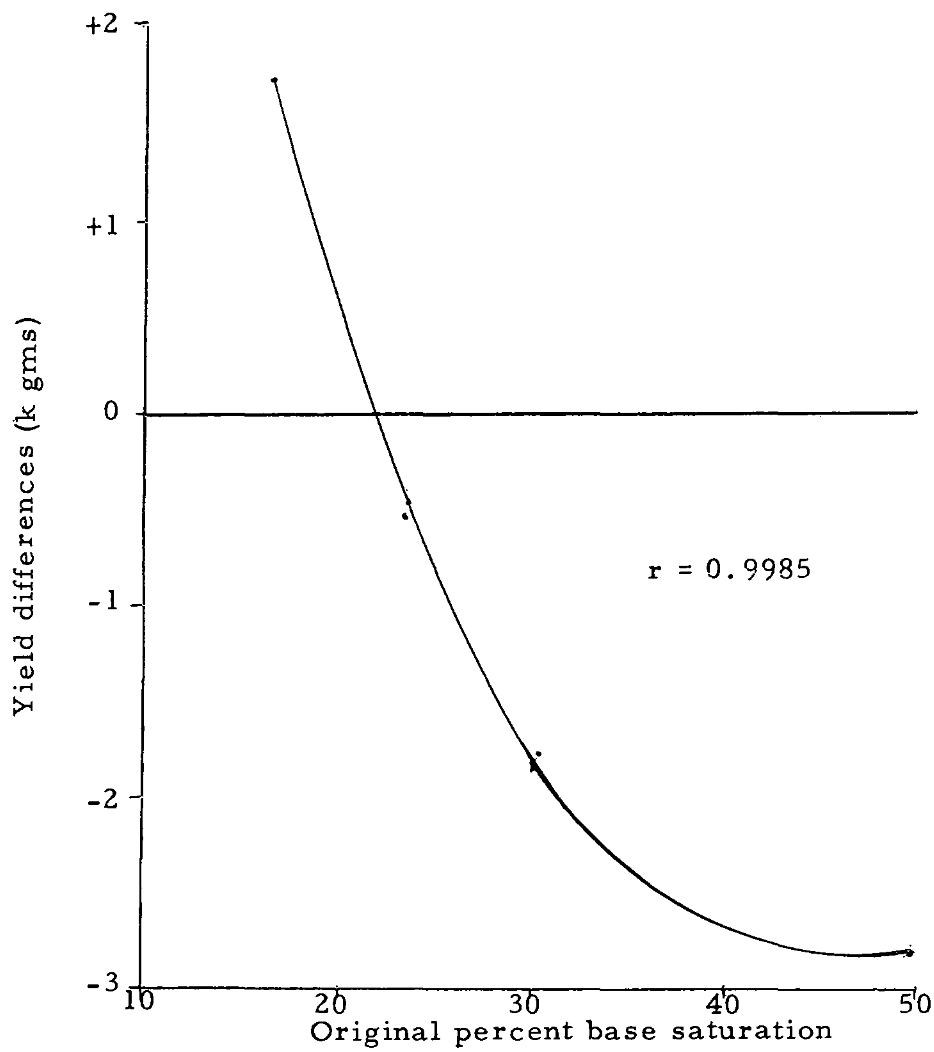

Figure 1. Comparison of yield differences and the original base saturation after increasing the base saturation.

decreased but will actually be increased by the addition of bases.

A possible explanation for the decrease in the yield of strawberries when they are limed, even though they are at a fairly low percentage base saturation, could be that when the lime or other materials are added, they increase the total salts in the soil to a point where the yield is decreased. An indication of this can be seen in Table 5. None of the values presented in this table are at the 1.5 mmhos per centimeter level which Bernstein (1965) reported would decrease the yield of strawberries by ten percent, but they are all higher than the untreated plots and this could have some effect on the yield. This theory is put forward for the reason that the effect of excess chloride on depressing yield is probably proportional to the amount of chloride and not a matter of reducing yield by ten percent at one point and having no effect at a lower level.

It is also most probable that under the conditions prevailing in Oregon that the total salt content of the soils are decreased during the winter because of the high amount of rainfall. If this is true, then, the total salt values given in Table 5 were probably higher during the previous fall in the critical period of fruit bud formation than they were in July.

Since it does not appear possible to increase the base saturation in an established strawberry planting without decreasing the yield, unless it is below the 20 percent level, it may be possible to make applications in advance of the planting of the berries by at least a year. This could be done before the last crop in the rotation ahead of the strawberries is planted. In this manner most of the soluble salts would be leached out by the winter rains or used by the cover crop. In this manner it may be possible to retain part of the bases added on the soil colloids but not have large quantities of them in the soil solution at one time.

Probably the reason there was an increased yield in the field which was below 20 percent base saturation was that the available base supply was so low that the benefits from increasing the supply outweighed the detrimental effects of the increased salts in the soil solution.

Chlorides

The results of the first greenhouse experiment are presented in Table 7. They are derived from a two week trial to study the effects of the chloride and sulfate ions on the growth of young strawberry transplants.

Table 7. Effects of the chloride and sulfate ion on young strawberry plants growing in nutrient culture for two weeks.

Treatment	No. of plants alive	No. of plants dead
Check	7	0
248 ppm Cl	1	6
496 ppm Cl	2	5
992 ppm Cl	0	7
384 ppm SO_4	6	1
576 ppm SO_4	4	3
768 ppm SO_4	7	0

The above table shows that the chloride ion is much more detrimental to the growth of a young transplant than is the sulfate ion. At the end of the two week period only three of the plants that had received chlorides remained alive, while only four of those that were receiving an amount of sulfate which was in excess of the standard in the base solution had died.

Figures 2, 3 and 4 are pictures taken of the plants when they were taken out of the nutrient solutions. Figure 2 is of the checks, i.e. the standard Hoagland's. Figure 3 is of plants from the 248 ppm chlorides, and Figure 4 is of plants from the 576 ppm sulfate treatment. These pictures show quite clearly the variation between the different treatments.

At the termination of the experiment, several of the healthy plants from the checks were transplanted into the crocks containing the different amounts of chlorides. Figure 5 shows one of the plants

Figure 2. Strawberry transplants grown in Hoagland's #2 nutrient solution for two weeks.

Figure 3. Strawberry transplants grown in Hoagland's #2 nutrient solution plus 248 ppm chloride for two weeks.

Figure 4. Strawberry transplants grown in Hoagland's #2 nutrient solution plus 768 ppm sulfates for two weeks.

Figure 5. Strawberry plants placed in Hoagland's #2 nutrient solution plus 992 ppm chloride for four days.

after it had been in 996 ppm chlorides for only four days. As can be seen from this picture, the plant had wilted severely in this short length of time even though it had been receiving a substantial amount of water. This would be in agreement with Bernstein's statement (1965) that strawberry plants grown in areas of high salt concentration tended to wilt earlier.

Table 8 contains the weights of mature plants that had been treated with varying degrees of chlorides and sulfates. These results show that in this experiment the sulfate ion had the most effect on the plants. This is probably explained by the fact that the sulfate ion was used in much higher concentrations than was the chloride ion, 192-576 ppm sulfate vs 0-250 ppm chlorides. This would be in agreement with Bernstein (1965) and Ehlig and Bernstein (1958) that strawberry plants are not particularly sensitive to one element over another but are sensitive to all salts.

In order to analyze statistically the results of this experiment, the different components were separated into different parts for analysis. This was done because the large differences in the sulfate treatments would tend to mask any differences in the chloride treatments, and therefore no significance would be seen between them. When weights of the chloride treatments alone, at the 192 ppm sulfate level, were analyzed by Analysis of Variance (Li, 1957), the F value obtained was significant at the one percent level. The sulfates

Table 8. Effects of the chloride and sulfate ions on the growth of mature strawberry plants grown in nutrient cultures for two months.

Treatment	Plant Weight in Grams			
	a	b	c	d
Check				
Fresh Wt.	45.5	42.7	49.0	39.7
Dry Wt.	12.9	12.5	13.0	12.3
62.5 Cl & 192 SO_4				
Fresh Wt.	47.9	39.3	38.3	dead
Dry Wt.	14.3	11.5	9.6	
125 Cl & 192 SO_4				
Fresh Wt.	29.7	26.3	21.1	9.1
Dry Wt.	7.8	7.8	7.2	2.5
250 Cl & 192 SO_4				
Fresh Wt.	25.3	39.1	14.6	dead
Dry Wt.	6.3	11.6	5.6	
0 Cl & 384 SO_4				
Fresh Wt.	48.8	21.3	15.7	dead
Dry Wt.	16.4	7.0	5.3	
62.5 Cl & 384 SO_4				
Fresh Wt.	21.7	dead	dead	dead
Dry Wt.	7.8			
125 Cl & 384 SO_4				
Fresh Wt.	18.5	10.0	dead	dead
Dry Wt.	5.4	4.6		
250 Cl & 384 SO_4				
Fresh Wt.	11.0	9.4	9.9	dead
Dry Wt.	5.5	2.7	2.8	

At all levels of chlorides plus 576 ppm sulfate plants die within the time of the experiment.

analyzed in the same manner, all at the 0 level of chlorides, also showed significance at the one percent level. These results show that both the sulfate and the chloride are highly effective in reducing the size of the strawberry plant when present in excessive amounts. The results of these first two experiments show that plant responses to chloride ions is much faster than to sulfate ions. This is in agreement with work of Ehlig and Bernstein (1958) where they found that both chlorides and sulfates are detrimental to the strawberry plant, but the sulfate ion requires longer to bring about this slowing of growth.

Figures 6 through 8 show some of the plants from the various treatments after they had been taken out of the nutrient solutions. Figures 6 and 7 show plants from the checks vs the 125 ppm chloride treatment. As can be seen plants from the 125 ppm chloride treatment are smaller than the check. Figure 8 is a picture of the plants which received the highest amount of salts, i.e. 250 ppm chloride and 576 ppm sulfates. All of the plants in this treatment died within the first month after starting the experiment.

Table 9 shows the mineral content of plants grown in nutrient solutions for two months. These readings are for the entire leaf, blade and petioles, since it was necessary to use the entire leaf in order to obtain enough sample on some of the smaller plants for the complete analysis. With the exception of the 0 chloride treatment,

Figure 6. One year old strawberry plants grown in Hoagland's nutrient solution for two months.

Figure 7. One year old strawberry plants grown in Hoagland's #2 nutrient solution plus 125 ppm chloride for two months.

Figure 8. One year old strawberry plants after two months in Hoagland's #2 nutrient solution plus 250 ppm chlorides and 576 ppm sulfate.

Table 9. Mineral content of strawberry plants grown in nutrient solutions for two months.

Treatment	Cl*	Ca	K	Mg	P
0 Cl & 192 SO_4**	.26	0.80	1.65	.200	.200
	.24	0.90	2.20	.286	.250
	.26	1.00	2.15	.300	.326
	.26	0.95	2.35	.330	.300
62.5 Cl & 192 SO_4	.24	0.95	2.10	.319	.270
	.26	1.05	2.40	.305	.326
	.33	0.70	1.75	.275	.236
125 Cl & 192 SO_4	.26	0.95	2.15	.319	.300
	.26	0.80	2.20	.300	.220
	.40	1.45	2.15	.370	.250
250 Cl & 192 SO_4	.33	1.05	2.20	.286	.270
	.24	0.85	2.15	.270	.250
	.26	0.85	2.40	.340	.326
0 Cl & 384 SO_4	.20	0.55	1.45	.225	.300
	.27	1.15	2.30	.360	.320
62.5 Cl & 384 SO_4	.39	1.30	2.00	.340	.236
125 Cl & 384 SO_4	.26	1.70	1.80	.335	.286
250 Cl & 384 SO_4	.26	0.85	2.25	.365	.300

* All values are given in percent of dry weight.

** Parts per million.

it was necessary to combine all the plants that remained alive in the treatment with 384 ppm sulfate in order to get enough sample for the various tests. In the case of the 0 ppm chloride treatment there was enough plant material for two different samples.

As can be seen from Table 9,, there were no differences in any of the treatments for the elements tested. Even the chloride content of the plants which was varied in the different solutions, was not different in the various treatments even though it had affected their weights. One possible reason for this apparent lack of variation between the different chloride treatments was the original chloride levels in the plants. The level of chlorides of the plants originally was 0.3 percent. This high level could explain the apparent lack of difference in the levels of chlorides in the plants at the end of the experiment. The lack of significance between the elements tested in the treatments indicates that the differences in weights of plants of the treatments is due to the physical presence of the salt in the solution rather than an inhibition of the uptake of one of the other elements.

In Table 10 the findings of the field survey, that was taken to determine if chloride damage was actually occurring in Oregon, are presented. In most of the fields sampled, there was an indication that some trouble existed. This trouble appeared to correlate with the fact that many of the fields were high in chlorides. Field

Table 10. Percentage chlorides found in the leaves of field grown strawberry plants.

Test Area	Variety	Percent Cl
1	Northwest	.64
2	Northwest	.33
	Shasta*	.33
	Shasta	.50
3	Northwest	.30
4	Northwest	.50
	Hood	.60
	Shasta	.60
5	Siletz	.18
	Molalla	.27
6	Northwest**	.53
7	Northwest	.25
8	Northwest	.46

* The two different samplings for Shasta from this grower represent samples taken from the same field but the plants come from different growers.

** Sample numbers six and seven are of transplants from different sources and therefore represent the chloride content of the entire top, rather than the leaves as the other samples represent.

samples were usually taken in places where the characteristic marginal leaf scorch was present, or there was evidence of a poor stand which might have resulted from chloride or high salt damage. This latter symptom was noted by Brown and Voth (1955) in strawberries irrigated with water that was moderately high in salt content. Young transplants so treated exhibited poor growth, general lack of vigor and a greater than normal mortality rate.

As can be seen from the data in Table 10, of the 12 samples taken, seven were above and five were below the critical level of 0.4 to 0.5 percent leaf chloride which is the point where leaf scorch begins. From these figures it can be seen that, even though it may or may not be a widespread phenomenon, damage is occurring in Oregon strawberry fields due to harmful levels of chlorides.

In Table 10, test area 2, plant samples for the varieties indicated were all taken in the same field, the only difference being that the two samples of Shasta plants came from different growers. The sample of Shasta that had 0.5 percent chlorides came from a grower in Oregon and the Shasta sample that had 0.33 percent chlorides came from a California grower. The plants growing side by side in the same field were very different in their appearances. Those that came from Oregon grew very poorly and there was a very high mortality rate among them, while those that came from California grew very well and most survived.

This difference in the chloride level of the two sources prompted a sampling of plants from other plant sources prior to field planting. Since it was in September, it was necessary to take samples that had been stored through the spring and summer. The results of this test are represented by samples six and seven. The levels of chlorides in these two sources are marked, one being fairly low and the other being approximately the level that causes marginal scorch in the leaves of plants.

This difference in the chloride content of the plants from different sources might explain a problem that had presented itself during the 1964 growing season. During this time several growers had problems with plants from different sources. The plants from one source grew normally, while plants from a different source responded very poorly even though they had received exactly the same treatment. This difference would often be seen to the exact row, where one plant source stopped and the other began. The symptoms exhibited were almost identical to those reported by Brown and Voth (1955).

The practice of Oregon's strawberry growers is to fertilize their young transplants very heavily at planting time, usually the same amount as is used on mature plantings. It is possible that with the sensitivity of the young plants to the chloride ion, as evidenced in the first experiment reported in this section, the large amounts of salts added to the soils are doing a great deal of harm to these young plants. This would be especially true in the case of the plants having a large amount of chlorides present in them at planting time (because of the fertilizer practices of the plant growers). It would also tend to be more of a problem where moisture levels became low following planting and fertilizing.

With these results in mind it might be well to consider a different form of potassium for at least the first year, and possibly for the other years. The levels mentioned in the introduction of this paper indicate that if all the potassium chloride that is applied by some growers to their strawberries were dissolved in two acre inches of water in the rooting zone of the plant, there would be approximately 250 ppm of chlorides in the soil water.

A soil sample taken in the field where sample number 1 of Table 10 was taken showed a concentration of 80 ppm chlorides in the saturation extract. Since the saturation extract is approximately four times as dilute as the soil solution at field capacity, the amount of chlorides present was well within the ranges where damage occurred in the second experiment reported in this section. In the case of transplants, the value mentioned above would be enough to either kill or severely stunt the plants.

In an effort to find another form of potassium to apply to strawberries, it might be well to consider potassium nitrate as it would eliminate the chloride ion, without introducing a second carrier ion that might increase the salt content of the soil. Further field research would be necessary before it could definitely be said that one form of potassium fertilizer is better for increasing yield than another, but the results presented herein strongly indicate that the chloride form is detrimental.

A further method for minimizing the adverse effects of high salts in the soil might be the application of more irrigation water to fields since salt content of the soil solution increases as soil dries out and the solution becomes more concentrated. Bernstein (1965) points out that infrequent irrigation intensifies salinity effects because the soil solution becomes progressively more saline as the soil dries out.

Results of this investigation indicate that losses can occur due to over fertilization. As was reported by Dalton (1963) it is possible to apply enough fertilizer to kill a bearing field. The amounts referred to above are greater than those that are generally used in Oregon, but they do show that it is possible to cause damage through the application of large amounts of salts to the field, either in the fertilizer program or through liming.

SUMMARY

Base Saturation

Research concerning increased base saturation was carried out in commercial fields. The findings are presented below.

1. In three out of the four fields in which yield data were taken, there was a reduction in the yield of treated as compared to non-treated plants.

2. When these differences in yields were plotted against the original percent base saturation, it was found that a relationship existed. When this was analyzed according to curvilinear regression, an r value of 0.9985 was obtained. This value indicates a significant relationship. From this data it was found that if the original percent base saturation is below 20 percent, an increase in yield can be expected.

3. Leaf samples indicated that there were no differences in the treatments over the checks for any element that was added except for magnesium and this was not different until July following a September application.

4. This lack of difference in the leaf elements indicated that the effect on the yield was due to an effect that

was occurring in the soil rather than in the plant itself. Soil samples had shown that the treated soils were higher in salts than the untreated checks, and it was postulated that these higher salts might be causing the differences in yields since strawberries are so sensitive to salts in the soil.

5. It was also postulated that it may be possible to increase the yield of strawberries by increasing the base saturation of the soil at least a year ahead of the planting of the strawberries. In this manner, if higher salts are actually causing problems in the liming of soils, there would be time for them to be leached out.

Chlorides

Three separate experiments were carried out in an effort to determine how sensitive the strawberry actually is to the chloride ion and whether damage is occurring in commercial plantings.

1. The first experiment was carried out in the greenhouse using young plants in sand cultures and irrigating as needed with nutrient solutions containing all of the required nutrients as well as the chloride and sulfate ions in certain treatments. Results

indicated that concentrations as low as 250 ppm of chloride caused the death of young plants within two weeks, while the plants withstood 768 ppm sulfates without any apparent harmful effects.

2. The second experiment was also carried out in the greenhouse, but mature plants were used and the concentrations of sulfates and chlorides were reduced to an upper limit of 250 ppm chlorides and 576 ppm sulfates. At the end of two months there was a statistical difference in the treatments which indicated that between 62.5 ppm and 125 ppm chlorides a reduction in plant size occurred. The sulfate treatments in this experiment also caused damage at the higher levels and at the highest level the plants died. These results were in agreement with those of other workers who reported all salts damage strawberries, but plants are damaged less rapidly by sulfates.

3. The third experiment conducted was a field survey to determine whether chloride damage was actually occurring in the fields. Seven out of twelve samples taken showed the chloride level to be in the critical range leading to the conclusion that chloride injury

is definitely occurring in Oregon strawberry plants and that measures should be taken to combat this damage.

4. A strong indication of a specialized case of chloride damage was also discovered. It was found that a high level of chlorides in the young transplants was associated with damage occurring in some fields. In these cases, plants from different sources behave quite differently under the same conditions in the field; some grew very poorly while others, growing beside them, grew quite well. It was found that some of these plants had high amounts of chloride in them when they were planted and that the addition of more chloride and/or allowing the fields to dry out could result in damage.

5. This information indicates that it might be worthwhile to use another form of potassium than chlorides, at least for the plant growers, and for the first year that the plants are in the field. One form that might be considered is the nitrate form as this would not only eliminate the chloride but would also decrease the salt index of the fertilizer.

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