THE EFFECT OF CERTAIN FERTILIZER TREATMENTS ON THE COMPOSITION OF B. C. INTERIOR FIELD TOMATOES WITH SPECIAL REFERENCE TO WATER-SOLUBLE PECTIN AS AN INDICATOR OF TOMATO FRUIT QUALITY.

by

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ABSTRACT

Investigation into possible causes for reported softness of B.C. Interior tomatoes revealed that processed tomatoes from the Kelowna district were firmer than processed tomatoes from the Vernon or Kamloops districts.

Soil and plant material samples from the Kelowna district were relatively high in calcium and magnesium and low in potassium compared to samples from Vernon which were relatively low in calcium and magnesium and high in potassium. Samples from the Kamloops district were relatively high in calcium, magnesium and potassium.

Fruit samples from the Kelowna district contained a significantly greater amount of water-soluble pectin than fruit from either Vernon or Kamloops. Soil treatments with several nutrient elements did not produce a significant effect on water-soluble pectin in tomato fruit at Kelowna, Vernon or Kamloops, but treatments containing calcium appeared to produce the most consistent effect.

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INTRODUCTION

About 2000 acres of fieldgrown tomatoes are planted in the B.C. Interior each year which makes them one of the most important vegetable crops of the area. This acreage is distributed between several districts including Keremeos in the Similkameen valley, Osoyoos in the south Okanagan, Kelowna in the central Okanagan, Vernon in the north Okanagan and Kamloops and Ashcroft in the Thompson river valley.

The tomato crop is sold both to processing companies and to the fresh market. The processing companies' main tomato product is canned whole tomatoes but they also manufacture some tomato juice and tomato puree. Tomatoes for the fresh market are packed as mature greens, semi-ripes or turnings by independent packing houses and sold through the Interior Vegetable Marketing Agency to markets in Vancouver to the west or as far east as Winnipeg.

Both the tomato processors and the fresh fruit market demand certain quality characteristics in the tomatoes that they buy and B.C. Interior tomato growers must produce tomatoes with those quality characteristics if they are to hold and expand those markets.

The fact that the tomato-growing industry has existed now for about fifty years indicates that B.C. Interior tomatoes have satisfied most of the quality requirements of the two markets but, in the last few years, there have been an increasing number of complaints from both markets concerning the quality of tomatoes grown in the B.C. Interior. Such complaints must be taken seriously because they indicate a condition that could jeopardize the success and future development of the B.C. Interior as a tomato-growing area.

The quality requirements of the two tomato markets are similar. Both require tomatoes that are medium sized, globe-shaped, free from cracks or blemishes and mildly acid in flavour. In addition, the processing market prefers tomatoes that are bright deep red in color and have the type of skin that peels easily. Tomatoes processed as canned whole tomatoes must also retain most of their wholeness in the can after being subjected to the handling procedures and high temperatures encountered during the canning process. Tomatoes for the fresh market must be able to develop an attractive red color when ripened off the vine after being picked and shipped in the green or semi-ripe state.

The main complaint from tomato processors concerning the quality of B.C. tomatoes is that the tomatoes lack firmness. Occasional complaints are voiced concerning lack of sufficient color development or too high acid content but these complaints usually occur only during abnormally cool seasons or at the cool end of an otherwise normal season. They are generally attributed to lack of sufficient heat for normal tomato development and are considered to be one of the normal hazards of producing a semi-tropical crop in a temperate climate. The condition of lack of firmness is considered to be more serious. It appears that in certain seasons or parts of seasons tomatoes processed as whole canned tomatoes tend to break down in the cans after processing. The result is a soft, mushy product that is downgraded because it lacks firmness.

Fresh fruit shippers, in recent years, have received complaints from the fresh fruit markets that B.C. Interior tomatoes have arrived at market in a soft, watery condition rendering them unfit for sale. On such occasions, rebates must be made to the buyers of such fruit and the B.C. industry loses a sale as well as being charged with the costs of packing and shipping. A more serious effect is the loss of reputation for quality that B.C. tomatoes have had in the fresh fruit markets.

Enquiry reveals that B.C. Interior tomatoes usually appear normal when freshly picked and only exhibit softness after processing or shipping. This makes difficult the task of tracing affected fruit back to particular farms or districts because the normal procedure of pooling and mixing lots of fruit at the packing shed or processing plant tends to cover up the identity of any particular lot. Another factor that hinders tracing the condition of softness of B.C. tomatoes to any particular cause is that the occurrence of softness sufficient to cause complaint is not consistent. During some seasons a particular district may be plagued with complaints for part of the season and then receive no complaints for the rest of the season. During other seasons some districts may have more complaints than other districts. There is no known case where all the tomato fruit from the entire area exhibited softness at one time or that all the fruit from one district exhibited softness at one time. Apparently, most districts receive complaints at some time or other, and some districts appear to receive more complaints than others. About the only generalization that can be made is that complaints about tomato quality are more common in the Kamloops and Vernon districts than they are in the Kelowna or other districts. The Osoyoos district which specializes almost entirely in producing early tomatoes for the fresh market receives occasional complaints about tomato quality, but most of the time fruit from that district is considered to be quite satisfactory. The Keremeos district has started producing tomatoes only recently. So far, few complaints have been received concerning the quality of tomatoes from there.

At present no definite cause is known for the condition of softness that occurs in B.C. Interior tomatoes but there are several popular opinions advanced by people connected with the industry. Among these opinions, the increasing incidence of tomato softness is blamed variously on the use of chemical fertilizers, use of too much nitrogen, insufficient use of potash, depleted soil organic matter, the increasing use of sprinkler irrigation and the change from older to newer varieties of tomatoes.

If there is truth in the statements heard that the problem of tomato softness is a fairly recent one that did not exist in earlier years of the industry, then such factors as newer varieties, depletion of soil organic matter, the use of chemical fertilizers instead of animal manures, changes in cultural practices such as changing from furrow irrigation to sprinkler irrigation, depletion of soil fertility by continued cropping and the recent introduction of tomato diseases all could be possible causes of deterioration of tomato quality in the B.C. Interior. The only way to prove or disprove the effect of the foregoing opinions would be by critical examination of each one. A more practical way to attempt to solve the problem would be to deduce from available facts the most likely possible causes and then subject them to experiment.

Some of the popular opinions regarding the cause of softness of B.C. Interior tomatoes can be eliminated or at least lowered in priority for critical examination. It is not likely that sprinkler irrigation would be a serious factor as a cause of tomato softness because the use of sprinkler irrigation is widespread and is known to be used in districts and on farms that show no apparent decline in tomato quality. On the other hand, some districts that report a high incidence of tomato softness still use more furrow irrigation than sprinkler irrigation. Tomato diseases would not appear to be a cause of tomato softness. The common tomato diseases present in the area are also present in most other tomato-growing areas and have not been reported to affect tomato firmness. The use of chemical fertilizers instead of animal manures is an accepted agricultural practice in all modern agricultural areas. Despite a preference for organic fertilizers by some people, chemical fertilizers are no longer considered to have any harmful effect on crops. A similar situation exists in regards to soil organic matter. Most agricultural opinion regards soil organic matter as a desireable fraction of any agricultural soil, but not absolutely essential for healthy plant growth. Experiments in which healthy plants are grown in sand or solution cultures have disproved the essentiality of organic matter in soils. The possible effect of changes in the varieties of tomatoes grown in the area is not known. Originally, the variety Earliana was grown for the fresh market and John Baer was grown for the processing market. These varieties have been superseded in recent years by such varieties as Clark's Early, Stokesdale, Gem and

Valiant. It does not seem likely that the newer varieties would be more susceptible to softness than the older varieties because they are grown in all districts and are also grown successfully in other tomato-producing areas. However, the fact that their introduction coincides somewhat with the development of complaints regarding tomato quality prevents the effect of variety from being excluded as a contributing factor to tomato softness.

The opinions that softness of B.C. Interior tomatoes is connected with declining soil fertility or the kinds of fertilizer used for tomato production merit serious consideration. It is possible that continuing vegetable production has produced certain soil nutrient deficiencies that are not being corrected by present fertilizer applications and that such deficiencies are responsible for softness of tomato fruit. The fact that occurrences of softness are sporadic but appear to be increasing in frequency and are inclined to show up in some districts more than others suggests that there may be a nutrient deficiency condition in the incipient stage. Such a condition could be more acute in some districts than others and possibly could be accentuated or repressed by climatic conditions in certain seasons or parts of seasons. A condition such as described would account for the sporadic occurrence of tomato softness, the fact that the fruit would not show signs of deficiency except under stress such as that encountered in shipping or processing, and the tendency for the trouble to be more severe in some districts than in others.

Nutrient elements at present recommended for use on field tomatoes in the B.C. Interior include nitrogen, phosphorus, potassium and boron (4). The most common fertilizer used for tomatoes is an 8-10-5 mix applied at about 500 pounds per acre. Nitrogen fertilizer, either in organic or inorganic form, is considered necessary for any plant growth in the area because the soil, under semi-arid conditions, does not accumulate nitrogen. The phosphorus status of the soils is not well known but is considered to be low, although phosphorus is not recommended for tree fruits in the area. B.C. Interior soils are considered to be well supplied with potassium. It has not been recommended for tree fruits for several years, but it is still used on tomatoes largely because it is advertised as having improved quality of tomatoes in other parts of the world. The area is considered to be generally deficient in boron and boron applications are recommended for all crops. No micronutrients other than boron are recommended for use on vegetable crops. Apparently, no deficiencies of other micronutrients have been recognized in vegetable crops although deficiencies of magnesium, manganese and zinc have been recognized in tree fruit crops and special recommendations are issued for their use on tree fruits (3). The soils of the area are considered to be well supplied with calcium. Some chlorotic conditions that appear on tree fruits in the area are considered to be caused by a lime induced iron deficiency.

In view of the fact that deficiencies of several nutrient elements are known to exist in the B.C. Interior and because the nutrient status of tomato-growing soils and tomato plants in the area is not well known, an investigation to determine the nutrient status of tomato soils and plants of the area would be desireable to see whether or not there could be a connection between nutrient status and the softness of fruit reported to exist in B.C. Interior tomatoes. It would also be of interest to apply and test the effect of several plant nutrients on the composition of the plants and the firmness of the fruit.

Because differences in the inherent firmness of B.C. Interior tomatoes often are apparent only after processing or shipping but difficult to detect in freshly picked fruit, some objective test would be useful that would reflect changes in the composition of fresh fruit that relate to firmness. Such a test would facilitate assessment of the effect of treatments intended to improve the firmness of the fruit.

In this study, several factors connected with tomato quality were reviewed, an investigative survey of districts producing extremes of tomato quality was made, a series of fertilizer experiments were conducted and an objective test reported to reflect changes in tomato quality was tried out in the hope that some of the information obtained would be useful to the tomato industry of the B.C. Interior.

REVIEW OF LITERATURE

"Quality" is a term used to describe the overall desireability of an article. It is the product of the effects of several component factors blended together to create a final impression. The effect of each of the factors is important but, in differing situations, the effect of some of the factors may be more important than others depending on the intended use for the article.

Tomato quality is composed of the effects of several factors. Some of the most important of these factors are: color, size, shape, flavor, freedom from blemishes, nutrient content and solidity.

The most generally desireable color for mature tomatoes is a bright, deep red. It has become the color typically associated with tomatoes of high quality and often exerts a decisive influence on the judgement of tomato quality by the consumer. The typical red color of tomato fruit is produced by the pigment lycopene, (6, 9) which is an isomer of the yellow pigment carotene (6). The final color of tomatoes is considered to be controlled by the carotene-lycopene ratio developed in the fruit (8, 9). Each variety of tomatoes develops a typical color at maturity so the carotene-lycopene ratio is affected by the genetic makeup of each variety (8). Some varieties are yellow-colored at maturity while other varieties are red-colored depending on the ratio of carotene to lycopene developed by the variety.

Mature tomato fruits do not always develop the typical color expected of the variety to which they belong. It has been found that the carotene-lycopene ratio can be affected by temperature and the normal development of lycopene suppressed (8, 17, 22). Apparently, the development of carotene is not affected by temperature (22) so it is common for presence of carotene to overbalance the effect of lycopene producing a yellow color in normally red-colored tomatoes but it is not possible for the development of lycopene to overbalance the effect of carotene and so produce redness in normally yellow-colored tomatoes. Lycopene does not develop normally at either low or high temperatures. It has been found that tomatoes matured at day temperatures of 60° F. and night temperatures of 45° F. did not develop their normal red color, or developed red color only after they were past optimum maturity (8, 22). On the other hand, varieties normally producing red-colored fruit, when matured at day temperatures of 100° F., produced yellow to orange-colored fruit (17, 22). The normal red color expected of red-colored varieties has been found to develop best at or around day temperatures of 80° F. and night temperatures of 65° F. (22). In experiments to determine the optimum temperature for artificially ripening tomatoes picked at the mature green stage, it was found that red color developed best at temperatures between 70° F. and 75° F. (25).

Each variety of tomato generally produces fruit of characteristic size and shape, but the size of fruit may be affected by cultural practices (20). It is common knowledge that fruit grown on plants well supplied with nutrients will be larger than fruit grown on plants deprived of any of the essential plant nutrients. The effect of adequacy or shortage of nitrogen probably has been noted more on the size of tomato fruit than any other plant nutrient element (20, 24).

The flavor of tomato fruit is associated with the acids and sugars developed in the fruit and the final flavor is considered to be controlled by the ratio of total sugars to total acids (23). The development of sugars is the result of photosynthetic activity and depends on the amount of sunlight absorbed by the plant (6, 14, 23). Some effect of cultural practices on the sugar content of tomato fruit has been reported (13, 21). High application rates of nitrogen have resulted in a decreased sugar content of tomato fruit (13) while high application rates of phosphorus and potassium are reported to have increased the sugar content (13).

The total acid content of tomato fruit is composed of several organic acids (6, 19) but it is the ascorbic acid fraction that has received the most investigation since ascorbic acid, also known as vitamin C, is the main nutritional factor associated with tomatoes. Ascorbic acid content is known to vary widely between varieties and between species of tomatoes. This knowledge is used to select parent material in tomato breeding programs designed to produce new tomato varieties of high ascorbic acid content (26). It is also known that the ascorbic acid content of the fruit of any one variety will vary considerably depending on climatic conditions. It was found that the ascorbic acid content varied directly with the amount and intensity of light available to the plant (14, 18). It was felt for some time that the amount of light absorbed by the plant foliage controlled the production of ascorbic acid (14), but lately it has been demonstrated that it is the amount of light absorbed by the fruit itself that affects the amount of ascorbic acid formed in the fruit (18). It has been found that the effect of light on ascorbic acid formation is cumulative and depends on the total amount of light absorbed by the fruit from the time of fruit formation until fruit maturity (18).

Factors thought to affect the firmness of tomatoes and other fruits have been investigated by many workers over a considerable period of time.

Appleman and Conrad (1) in 1926 investigated the relationship of water-soluble pectin, acid-hydrolyzable pectin or protopectin, and total pectin in the fruit as it occurs during the normal ripening of peaches. They concluded that, as ripening progresses accompanied by consequent softening, protopectin is changed to water-soluble pectin at a rate paralleling the degree of ripening and softening; but that, at any stage of ripening, the total pectin remains almost constant. The same workers (2) in 1927 investigated the relationship of pectic substances to the degree of ripening and softening of fresh tomatoes. They concluded that, as fresh tomatoes ripen from green to full ripe with consequent softening, protopectin is converted to water-soluble pectin but, as in the case of peaches, the total pectin remains almost constant. They also correlated the ratio of water-soluble pectin to protopectin with the degree of disintegration that takes place during the processing of whole tomatoes. They found that as the pectin-protopectin ratio increased the degree of disintegration, as measured by a sieve test, also increased. Their general conclusions were that firmness in fruit is dependent on the amount of protopectin present and that, as protopectin is changed to water-soluble pectin, progressive softening of the fruit occurs.

In 1934, Degman and Weinberger (7) studied the effects of nitrogen and potassium fertilizers on the firmness and keeping qualities of apples and peaches. They concluded that nitrogen did not affect the firmness of either fruit and that, of several potassium containing fertilizers, only one that also contained magnesium produced a fruit firming effect. They also concluded that pectic materials are closely related to firmness and that protopectins change to water-soluble pectins as ripening and softening of fruit takes place.

Krausche and Gilbert (20) in 1936 investigated the effect of nitrogen fertilizers on the fleshiness and firmness of tomatoes. They concluded that, although high nitrogen treatments resulted in fruit with a lower ratio of fleshy wall material to cross-section area, the fruits produced from high nitrogen treatments appeared to be firmer than those from low nitrogen treatments.

Sorenson and Alley (24) investigated the relationship of high nitrogen fertilizer treatments to the ability of green-wrap tomatoes to withstand long distance shipping. They concluded that high nitrogen treatments had no adverse effect on the firmness or shipping qualities of tomatoes.

Calcium is commonly added to commercially processed whole tomatoes to improve their firmness. It is usually added in the form of calcium chloride-sodium chloride tablets. Gould, Davis, Krantz and Healy (12) have reported that the addition of calcium chloride to processed tomatoes had sufficient firming effect to raise the quality rating one U.S. grade. Hamson (15) found that calcium chloride would increase the firmness of soft tomatoes but had no appreciable effect on tomatoes that were already reasonably firm. Kertesz (19) states that, when calcium chloride-sodium chloride tablets are added to processing tomatoes, calcium combines with demethylated pectin to form a calcium pectate gel which produces the firming effect usually noted.

Hamson (15, 16) noted that certain varieties of tomatoes always produced firmer fruits than other varieties grown under identical conditions. He found that the fruits from the firm-fruited varieties always contained a higher percentage of calcium than the fruits from soft-fruited varieties showing that some varieties apparently had a greater ability to take up calcium from the same nutrient medium. He also found that fruit from firm-fruited varieties contained more of the demethylating enzyme, pectin methylesterase, than fruit from soft-fruited varieties. From this work of Hamson and that of Kertesz (15, 16, 19) it appears that, when pectin methylesterase demethylates the pectin in tomatoes, a calcium pectate gel is formed which has a firming effect on the fruit and also establishes a calcium gradient in the plant with the result that a greater amount of calcium is taken up from the nutrient medium.

Hamson (16) also obtained positive correlations between water-soluble pectin, acid-soluble pectin, ammonium oxalate-soluble pectin and total pectin with firmness of tomato fruits as measured by a pressure tester, provided that the fruits being tested were at a comparable stage of ripeness.

The literature reviewed reveals that there are many influences that affect the quality of tomato fruit. The color of the fruit is affected by variety and temperature (6, 8, 9, 17, 22, 25). The size and shape of the fruit are affected by variety and cultural practices (20, 24). The flavor of the fruit is affected by variety, sunlight and cultural practices (6, 13, 14, 21, 23). The vitamin C content of the fruit is affected by variety and light (14, 18, 26). The firmness of tomato fruit appears to be related to calcium content (11, 12, 15, 16, 19) which in turn may be affected by variety (15, 16) and by nutrition (10, 11). Tomato fruit firmness also appears to be related to pectin content which may be affected by variety (15, 16), maturity (1, 2, 7, 19) and calcium content (15, 16).

The work of Hamson (15, 16) suggests that, provided one tomato variety is considered at a time and provided fruits of the same maturity are used, comparative analysis of tomato fruit for any of the pectic fractions will reveal differences in tomato fruit firmness. If such is the case, comparative analysis for any of the pectic fractions should reveal any effect on the firmness of tomato fruit from treatments designed to affect firmness.

MATERIALS and METHODS

1953 Preliminary Survey

No data were available at the start of this investigation concerning the nutrient status of tomato plants or tomato-growing soils in the B.C. Interior. A preliminary survey was made, therefore, in 1953 in which samples of soil, tomato leaves and tomato fruit were collected from selected tomato fields in each district in the area and analysed at the Plant Nutrition Laboratory of the Summerland Experimental Farm.

Soil samples were taken to six and twelve inch depths. They were screened through one-eighth inch screening to remove rocks and debris, then extracted by the carbon dioxide method. The extracts were analysed by standard laboratory methods for pH, conductivity, phosphorus, calcium and magnesium.

Leaf samples were taken from recently matured sections of the plants. They were dried, ashed, and then extracted with five per cent hydrochloric acid. They were analysed by standard laboratory methods for nitrogen, phosphorus, potassium, calcium, magnesium and boron.

Fresh fruit samples were sectored and frozen, then dried, ashed, and extracted with five per cent hydrochloric acid. They were analysed for nitrogen, phosphorus, potassium, calcium and magnesium by standard laboratory methods.

Fruit samples were also collected and processed as whole, canned tomatoes. They were picked at the fully ripe stage, and processed by standard processing methods at the Fruit and Vegetable Processing Laboratory of the Summerland Experimental Farm. They were stored for two months and then examined for firmness and wholeness by experienced staff members.

<u>1954 Fertilizer Experiments</u>

Information obtained from the 1953 preliminary survey indicated that there was a difference in quality between processed tomato samples from the Kelowna district and those from the Vernon and Kamloops districts. There were also differences in the levels of calcium, potassium and magnesium in soil, leaf and fruit samples obtained from those districts. This information was used to choose sites in those three districts for a fertilizer experiment in which the effects of several plant nutrients on the composition of tomato plants and on the quality of tomato fruit would be noted.

An experimental plan was prepared in which soil treatments of boron, manganese, magnesium, zinc, copper, calcium, calcium plus boron and a nutrient mix would be applied in a 9 x 5 randomized block design as shown in figure 1. The same plan was used in each of the districts of Kelowna, Vernon and Kamloops.

Block I	2	5	3	7	9	4	8	6	1
Block II	1	4	2	8	5	9	6	3	7
Block III	6	8	1	3	4	7	5	2	9
Block IV	7	9	6	5	2	1	3	8	4
Block V	5	7	9	1	3	8	2	4	6

Fig. 1. Randomized 9 x 5 Block Arrangement Used at the Three Experiment Locations.

Each of the nine treatments was given a number and this same numbering system was used at the three locations. The treatments, with treatment numbers, nutrient element concerned, material used to supply the nutrient element and per acre application rates of the materials supplying the nutrients, were as follows:

Treatment No.	Element	Material Used	Rate (Lb. per acre)
1	Boron	Sodium tetraborate	20
2	Manganese	Manganese sulphate	20
3	Magnesium	Magnesium sulphate	40
4	Zinc	Zinc sulphate	20
5	Copper	Copper sulphate	20
6	Calcium	Calcium sulphate	1000
7	Ca. + B.	No. 1 + No. 6	1020
8	Mix	Nos. 1 to 6 mixed	1120
9	Check	No Treatment	--

With the exception of the calcium sulphate treatment, each treatment material was dissolved in water and applied to the designated plot areas from a watering can. Calcium sulphate was spread in the dry form. In addition to these treatments, each plot area was fertilized with 8-10-5 fertilizer at the rate of 500 pounds per acre. After all treatments were applied, the soil in each plot area was cultivated to mix the treatment materials in to root depth.

Each treatment plot contained sixteen test plants of Clark's Early variety planted four feet apart in a 4 x 4 pattern. Guard rows separated each treatment plot from other treatment plots.

Leaf samples were collected from the plots in mid-season. They were dried, ashed, extracted with five per cent hydrochloric acid and analysed by standard laboratory methods for phosphorus, potassium, magnesium and boron.

A four pound sample of firm mature fruit was selected at random from each plot in mid-September. Each fruit was sectored and enough sectors were taken to fill a pint-sized freezer carton. The cartons of fruit sectors were fast frozen at commercial freezing establishments in the locality and then transported to the Summerland Experimental Farm where they were stored at 0° F.

Because the work of Hamson (15, 16) and others (1, 2, 7, 19) indicated that pectin was associated with the quality of firmness of tomatoes and other fruits, and because Hamson's work (15) indicated that comparative levels of water-soluble pectin could be used as a measure of comparative firmness of tomatoes, the frozen samples of tomato fruit from the treatment plots were analysed for water-soluble pectin. It was hoped that any differences in water-soluble pectin found in fruit from plots under various treatments could be used to determine the effect, if any, that the nutrient treatments had on the quality of firmness of the tomato fruit.

Water-soluble pectin content of the tomato samples was determined by a modification of Carrē and Haynes method (5) as used by McInney of the Food and Drug Laboratories, Division of Chemistry, Central Experimental Farm at Ottawa. The frozen samples were thawed, then macerated and mixed in a Waring Blendor. Duplicate aliquots of 100 gm. each were diluted with 400 ml. of distilled water, boiled for one hour and then filtered. From the filtrate a 100 ml. aliquot was made up to 400 ml. with distilled water; 10 ml. 1N NaOH was added and the solutions were allowed to stand overnight. The following morning, 50 ml. of 1N acetic acid was added; the solutions were allowed to stand for five minutes, then 50 ml. of 1N calcium chloride was added and the solutions were allowed to stand for one hour. The solutions were then heated to boiling for one minute and then filtered through #41 Whatman filter papers. The jelly-like precipitate that collected on the filter papers was washed with near-boiling water until free from chlorides. It was then washed into a weighed aluminum drying can and dried first over a water bath and then overnight in a drying oven at 100° C. In the morning, the cans were removed from the drying oven, cooled in a desiccator, and then weighed. The weight of the dry precipitate was calculated by subtraction and considered to be calcium pectate or water-soluble pectin. Calculations were then recorded on the basis of water-soluble pectin per 100 gm. of original tomato fruit material.

1955 Phosphorus Experiment

A separate preliminary investigation into the effect of nitrogen, phosphorus and potassium on the yield of B.C. Interior tomatoes had indicated that both nitrogen and phosphorus increased yields. There was also an indication that phosphorus produced a beneficial effect on fruit quality. To further test this effect, a phosphorus experiment was carried out at Vernon in 1955.

Superphosphate (0-19-0) was applied to test plots at rates to supply 0, 100, 200 and 300 pounds of P_2O_5 per acre. Each treatment was replicated six times in a 4 x 6 randomized block. The entire block was fertilized with ammonium nitrate (33-0-0) at a rate to supply 80 pounds of nitrogen per acre. The block was cultivated to mix the fertilizer materials in to root depth.

Each treatment plot contained sixteen test plants of Clark's Early variety planted four feet apart in a 4 x 4 pattern. Guard rows separated each treatment plot from other treatment plots.

Leaf samples were collected from the plots in mid-season. They were dried, ashed, extracted with five per cent hydrochloric acid and analysed by a standard laboratory method for phosphorus.

Samples of fully ripe fruit were picked at random from each treatment plot in mid-September. These were processed as whole canned tomatoes under standard processing conditions by the Fruit and Vegetable Processing Laboratory of the Summerland Experimental Farm. The canned samples were stored for two months and then opened and judged for wholeness and firmness by an experienced panel of the Fruit and Vegetable Processing Laboratory staff. Results were recorded as mean points for each treatment out of a possible forty-five points.

RESULTS

1953 Preliminary Survey

When the samples of processed tomatoes from the various districts were examined for the qualities of firmness and wholeness, it was the unanimous opinion of the judging panel that the firmest samples were those from the Kelowna district and the softest samples were those from the Vernon and Kamloops districts. The nutrient status of soil, leaf and fruit samples from those districts then became of immediate interest as a source of information to explain the contrasts in fruit quality. Analytical results from soil, leaf and fruit samples from fields within those districts that were selected as sites for a fertilizer experiment in 1954 are presented in tables 1, 2 and 3.

TABLE 1. ANALYSIS OF SOIL SAMPLES TAKEN IN 1953 FROM SITES USED FOR FERTILIZER EXPERIMENTS IN 1954.

Locality	pH	Cond.	P p.p.m.	K p.p.m.	Ca p.p.m.	Mg p.p.m.
Kelowna	7.8	55	33.77	38.75	1210	265.5
Vernon	6.8	471	36.55	115.00	275	50.5
Kamloops	8.0	173	10.04	123.75	1450	336.2

It will be noted from table 1 that there was considerable variation in soil analyses between the three localities. Soil pH at Kelowna and Kamloops was considerably higher than it was at Vernon. This appears to correlate with levels of calcium and magnesium at those localities. Conductivity was highest at Vernon and lowest at Kelowna. This may be related, in part, to levels of potassium, but could also be related to the presence of other minerals such as sodium that were not determined. Phosphorus levels were similar at Kelowna and Vernon and lower at Kamloops. Potassium levels were considerably higher at Vernon and Kamloops than they were at Kelowna. This appears to be the first instance in which there was a definite difference between the two localities that produced the poorest fruit and the locality that produced the best fruit. Calcium and magnesium were both considerably lower at Vernon than at either Kelowna or Kamloops.

TABLE 2. ANALYSIS OF TOMATO LEAF SAMPLES TAKEN IN 1953 FROM SITES USED FOR FERTILIZER EXPERIMENTS IN 1954.

(dry weight basis)

Locality	N %	P %	K %	Ca %	Mg %	B p.p.m.
Kelowna	3.21	.252	1.81	6.90	.779	91
Vernon	3.60	.390	3.88	4.70	.321	108
Kamloops	3.33	.205	2.15	6.00	1.060	51

Data from analysis of tomato leaf samples collected at Kelowna, Vernon and Kamloops are presented in table 2. Nitrogen levels did not vary greatly between the three localities. Phosphorus was higher at Vernon than at Kelowna or Kamloops. Potassium was much higher at Vernon than at Kelowna. Calcium was higher at Kelowna and Kamloops than at Vernon. Magnesium was highest at Kamloops, next highest at Kelowna and lowest at Vernon. Boron levels were in a similar range at Kelowna and Vernon but lower at Kamloops.

TABLE 3. ANALYSIS OF TOMATO FRUIT SAMPLES TAKEN IN 1953 FROM SITES USED FOR FERTILIZER EXPERIMENTS IN 1954.

(dry weight basis)

Locality	N %	P %	K %	Ca %	Mg %
Kelowna	2.28	.377	3.02	.232	.103
Vernon	2.53	.462	4.12	.175	.115
Kamloops	2.73	.289	3.56	.136	.134

Data from analysis of fruit samples collected at Kelowna, Vernon and Kamloops are presented in table 3. Nitrogen levels were similar in the samples from the three localities. Phosphorus was highest in the Vernon samples. Potassium also was highest in the Vernon samples. Calcium was highest in the Kelowna samples. Magnesium levels were similar in samples from the three localities.

The data that appear in tables 1, 2 and 3 did not supply a readily apparent reason why tomato fruit samples from Kelowna were better than those from Vernon or Kamloops. There appeared to be a definite contrast between Kelowna and Vernon in that samples from Kelowna were low in potassium and high in calcium and magnesium while samples from Vernon were high in potassium and low in calcium and magnesium. The contrast did not hold with the Kamloops samples which were relatively high in potassium, calcium and magnesium.

1954 Fertilizer Experiments

Tables 4, 5 and 6 present the results of analysis of tomato leaf material from the fertilizer experiment blocks at Kelowna, Vernon and Kamloops. Each value given is the average of five replicate samples from each treatment.

TABLE 4. ANALYSIS OF TOMATO LEAF MATERIAL FROM THE KELOWNA FERTILIZER EXPERIMENT.

Treatment No.	Element Applied	P %	K %	Mg %	B p.p.m.
1	B	.232	.865	1.183	107
2	Mn	.223	.745	1.088	46
3	Mg	.241	.950	1.118	54
4	Zn	.232	.979	1.161	41
5	Cu	.211	.700	1.174	49
6	Ca	.222	1.015	1.190	51
7	Ca + B	.227	.775	1.156	98
8	Mix	.231	.810	1.245	104
9	Check	.236	.855	1.162	59

It will be noted from the data in table 4 that boron was the only analysed element that was affected by the fertilizer treatments at Kelowna. Each treatment that contained boron resulted in practically doubling the boron content of the tomato leaves.

TABLE 5. ANALYSIS OF TOMATO LEAF MATERIAL FROM THE VERNON FERTILIZER EXPERIMENT.

Treatment No.	Element Applied	P %	K %	Mg %	B p.p.m.
1	B	.357	2.66	1.000	55
2	Mn	.346	2.80	.930	31
3	Mg	.346	2.79	.953	25
4	Zn	.333	2.90	.900	28
5	Cu	.350	2.94	.955	34
6	Ca	.323	2.89	1.047	20
7	Ca + B	.352	2.93	.950	63
8	Mix	.362	2.53	.984	64
9	Check	.344	2.89	1.137	34

Data presented in table 5 indicate that boron was the only analysed element affected by the fertilizer treatments at Vernon. The boron content of tomato leaves was practically doubled by each treatment that included boron.

TABLE 6. ANALYSIS OF TOMATO LEAF MATERIAL FROM THE KAMLOOPS FERTILIZER EXPERIMENT.

Treatment No.	Element Applied	P %	K %	Mg %	B p.p.m.
1	B	.242	2.10	1.201	71
2	Mn	.210	2.26	1.217	17
3	Mg	.226	2.06	1.221	21
4	Zn	.231	2.34	1.166	23
5	Cu	.209	2.06	1.243	19
6	Ca	.248	2.18	1.196	24
7	Ca + B	.217	2.11	1.254	59
8	Mix	.233	2.28	1.218	54
9	Check	.238	2.07	1.225	20

Data presented in table 6 indicate that boron was the only element affected by the fertilizer treatments at Kamloops. The boron content of tomato leaves was doubled by each treatment that included boron.

Data presented in tables 2, 4, 5 and 6 show that comparative levels of phosphorus, potassium and magnesium in leaf samples from the three experimental sites were similar in 1953 and 1954. In both years, phosphorus levels were highest at Vernon, potassium levels were highest at Vernon and lowest at Kelowna, and magnesium levels were highest at Kamloops and lowest at Vernon. In 1954, boron content of tomato leaves was significantly increased at each of the experimental sites by treatments containing boron.

The results of water-soluble pectin analyses of fruit samples from fertilizer treatment plots at Kelowna, Vernon and

Kamloops are presented in tables 7, 8, 9 and 10. Table 7 presents a summary of the mean water-soluble pectin content of fruit from each treatment in the three districts and allows comparison of the general mean water-soluble pectin contents of fruit from the three experimental blocks. The results of treatment replicates for each district are presented in tables 8, 9 and 10.

It will be noted from table 7 that there was a significant difference between the general mean pectin content in tomato fruit from the Kelowna district compared to the general mean pectin contents of fruit from either Vernon or Kamloops, but that there was no significant difference between the general means of Vernon and Kamloops.

Data in tables 8, 9 and 10 show that there was no significant effect of any of the treatments on water-soluble pectin content of tomato fruit at any of the three localities. A large amount of variation is apparent between analyses of replicates from the same treatments. This fact undoubtedly affected the degree of difference required for statistical significance.

It may be noted that the greatest apparent effect on water-soluble pectin was obtained from treatments containing calcium at Kelowna; boron, zinc, copper, and calcium plus boron at Vernon; and manganese, calcium and calcium plus boron at Kamloops. It is apparent that the effect of locality was greater than the effect of any of the fertilizer treatments that were used.

TABLE 7.

THE EFFECT OF FERTILIZER TREATMENTS ON THE WATER-SOLUBLE PECTIN CONTENT OF FIELD TOMATOES AT THREE LOCATIONS IN THE B.C. INTERIOR.

Treatment No.	Treatment	Water-soluble pectin. mg./100g.fresh fruit		
		Kelowna	Vernon	Kamloops
1	Boron	33.2	26.2	22.0
2	Manganese	32.8	22.6	25.0
3	Magnesium	34.0	19.4	22.0
4	Zinc	32.0	24.8	22.2
5	Copper	33.8	24.8	20.2
6	Calcium	36.8	22.8	27.0
7	Ca. + B	38.2	25.4	24.4
8	Mix	39.2	22.6	24.2
9	Check	35.0	21.2	18.6
District means		35.0 ☆☆	23.3	22.8

L.S.D. between district means (P = 0.01) = 3.06 mg./100g.

TABLE 8.

KELOWNA EXPERIMENT. WATER-SOLUBLE PECTIN RECOVERED AS CALCIUM PECTATE.

(mg./100 g. fruit material)

Treatment No.	Replications					Treatment totals	Treatment means
	1	2	3	4	5		
1	21	33	35	37	40	166	33.2
2	40	35	35	29	25	164	32.8
3	34	36	38	35	27	170	34.0
4	42	32	32	29	25	160	32.0
5	38	36	35	35	25	169	33.8
6	45	38	33	39	29	184	36.8
7	47	31	35	37	41	191	38.2
8	44	36	42	36	38	196	39.2
9	36	30	28	45	36	175	35.0
Totals	347	307	313	322	286	1575	
Means	38.5	34.1	34.7	35.7	31.7	175	35.0

L.S.D. between treatment means (P = 0.05) = 7.16 mg./100g.

TABLE 9.

VERNON EXPERIMENT. WATER-SOLUBLE PECTIN RECOVERED AS CALCIUM PECTATE.

(mg./100 g. fruit material)

Treatment No.	Replications					Treatment totals	Treatment means
	1	2	3	4	5		
1	25	34	32	23	17	131	26.2
2	26	32	18	14	23	113	22.6
3	17	10	31	18	21	97	19.4
4	26	29	22	22	25	124	24.8
5	27	28	21	22	26	124	24.8
6	32	26	24	20	12	114	22.8
7	36	17	24	37	13	127	25.4
8	14	19	33	26	21	113	22.6
9	32	16	12	21	25	106	21.2
Totals	235	211	217	203	183	1045	
Means	26.1	23.4	24.1	22.5	20.3	116.5	23.3

L.S.D. between treatment means ($P = 0.05$) = 9.32 mg./100g.

TABLE 10.

KAMLOOPS EXPERIMENT. WATER-SOLUBLE PECTIN RECOVERED AS CALCIUM PECTATE.

(mg./100 g. fruit material)

Treatment No.	Replications					Treatment totals	Treatment means
	1	2	3	4	5		
1	25	37	20	15	13	110	22.0
2	37	19	36	16	17	125	25.0
3	22	35	20	22	11	110	22.0
4	18	27	28	16	22	111	22.2
5	19	29	25	15	13	101	20.2
6	18	31	21	38	27	135	27.0
7	19	38	22	23	20	122	24.4
8	23	21	24	33	20	121	24.2
9	13	20	20	24	16	93	18.6
Totals	194	257	216	202	159	1028	
Means	21.5	28.5	24.0	22.4	17.6	114.2	22.8

L.S.D. between treatment means (P = 0.05) = 8.85 mg./100 g.

1955 Phosphorus Experiment

Data from the phosphorus experiment carried out at Vernon in 1955, at a site different from the one used for the Vernon fertilizer experiment in 1954, are presented in table 11. The initial interest in this experiment had been primarily concerned with the effect of increasing increments of phosphorus on tomato yield. No significant effect on yield was obtained, but a significant increase in the firmness of tomato fruit after processing was obtained from treatments with increasing rates of phosphorus.

The data in table 11 show that, as treatment rates of phosphorus increased, there was a definite increase in the amount of phosphorus present in tomato leaf tissue. This effect was highly significant at the rate of 200 pounds P_2O_5 per acre. The effect appeared to be levelling out at that rate because the next 100 pound increment produced only a slight increase in leaf phosphorus.

The data in table 11 also show that, as treatment rates of phosphorus increased, there was a definite increase in the firmness ratings of processed tomato samples from the treatment plots. A significant increase in firmness was obtained from the rate of 100 pounds P_2O_5 per acre and the firmness ratings continued to increase through the 300 pound P_2O_5 per acre rate.

It should be noted that the leaf phosphorus level of the untreated plots in this experiment was considerably lower than the leaf phosphorus levels at a different site in Vernon in

1953 and 1954 as recorded in tables 2 and 5. The highest level of leaf phosphorus obtained from the 300 pound P_2O_5 per acre treatment was still lower than leaf phosphorus levels at the other site in Vernon.

TABLE 11.

THE EFFECT OF PHOSPHORUS FERTILIZER TREATMENTS ON THE PHOSPHORUS LEVELS IN TOMATO LEAVES AND THE FIRMNESS RATING OF PROCESSED TOMATO FRUIT IN A PHOSPHORUS FERTILIZER FIELD EXPERIMENT CONDUCTED AT VERNON IN 1955.

Treatment. Lb. P_2O_5 per acre (from superphosphate 19%)	Leaf phosphorus. % of dry weight.	Quality rating of canned tomatoes. Firmness score.
0	0.194	21.16
100	0.221	29.16 *
200	0.256 **	30.16 *
300	0.258 **	34.33 **
L.S.D. (P = 0.05)	0.034	6.58
L.S.D. (P = 0.01)	0.048	9.10

DISCUSSION

1953 Preliminary Survey

The preliminary survey of 1953 appeared to serve a useful purpose in that it revealed differences in quality of tomato fruit from different districts in the B.C. Interior and also revealed that there were differences in levels of plant nutrients in the soils of those districts.

The districts chosen for further experiments were those that showed the greatest difference in fruit quality. Fruit from other districts covered in the survey was of intermediate quality and consequently of less interest than the two extremes.

It is perhaps unfortunate that the quality ratings given to the survey fruit samples were not based on an objective test that resulted in a definite number of points for each sample such as those recorded in the 1955 phosphorus experiment, but the methods of such a test were not worked out until later. However, the method of judging in which the samples were rated good, fair or poor, was precise enough to separate the two quality extremes.

The most interesting points derived from the survey sample analyses appeared to be that Kelowna, the district producing the best tomato fruit quality, was low in potassium, high in calcium and moderately well supplied with magnesium, compared to Vernon which was high in potassium, and low in calcium and magnesium. Potassium is widely promoted as a quality producing element and it has been applied to Interior field tomatoes with the intent to improve tomato quality, but in this survey the best quality tomatoes were produced in soil relatively low in potassium, and the poorest quality tomatoes were produced in soil relatively high in potassium.

Most B.C. Interior soils are considered to be well supplied with calcium, but Vernon appears to have considerably less calcium than Kelowna or Kamloops. The low calcium content in the Kamloops fruit sample appeared to be an anomaly considering the amount of calcium in the Kamloops soil and leaf samples.

1954 Fertilizer Experiments

The fact that boron treatments resulted in 100 per cent increases in the boron content of tomato leaves at the three experimental sites, indicates the effectiveness of the boron-supplying material and the rates used. Whether or not the levels obtained as a result of treatment are desirable is not known. They appeared to produce an increase in pectin content at Vernon and a slight increase when combined with calcium at Kelowna, but none at Kamloops.

Magnesium treatments did not produce an increase in leaf magnesium even at Vernon, the district lowest in magnesium. This suggests that the rates used were too low to produce an effect from the type of material used.

Results of the pectin analyses showed that the general mean level of pectin in tomato fruit was higher at Kelowna than at Vernon or Kamloops. This fact in conjunction with the observation that tomato firmness was greater at Kelowna than at Vernon or Kamloops appears to substantiate Hamson's statement (15) that water-soluble pectin content is directly related to firmness of tomatoes. In that case, water-soluble pectin content should be a useful indicator to determine the effect of any treatment intended to increase the firmness of tomato fruit.

The fact that no significant increase in water-soluble pectin was obtained at any of the experimental sites from any of the fertilizer treatments used does not necessarily condemn the usefulness of water-soluble pectin as an indicator of tomato firmness. It may mean only that an effective treatment was not included in this experiment, or that the rates were not high enough to produce a significant effect.

The fact that calcium treatments produced the most consistent increase in water-soluble pectin, in conjunction with the fact that the Kelowna district, which had high calcium levels, produced the firmest fruit and the fruit with the highest water-soluble pectin content agrees with Hamson's statement (15) that firmness, calcium content and water-soluble pectin content are directly related in tomato fruit.

1955 Phosphorus Experiment

The results of the 1955 phosphorus experiment are interesting because a definite increase in tomato firmness was obtained from a fertilizer treatment. The data suggest that the increase in firmness was the result of an increased uptake of phosphorus by the plants, but there are some hazards in that conclusion.

In the experiment, phosphorus was supplied by superphosphate which is known to contain calcium as well as phosphorus. It is possible that increased phosphorus intake was accompanied by increased calcium intake and that the increased calcium content resulted in increased firmness of the fruit.

No firm conclusions can be drawn from this experiment until further analysis of the plant material is made except that increasing increments of superphosphate fertilizer resulted in increased firmness of the tomato fruit.

CONCLUSIONS

Processed tomato fruit samples from the Kelowna district were firmer than samples from other districts in the B.C. Interior.

Processed tomato fruit samples from the Vernon and Kamloops districts were softer than samples from other districts in the B.C. Interior.

Samples of soil, tomato leaf material and tomato fruit from the Kelowna district were relatively high in calcium, low in potassium and moderately high in magnesium.

Samples of soil, tomato leaf material and tomato fruit from the Vernon district were relatively low in calcium, high in potassium and low in magnesium.

Samples of soil, tomato leaf material and tomato fruit from the Kamloops district were relatively high in calcium, high in potassium and high in magnesium.

Frozen samples of fresh tomato fruit from the Kelowna district contained a significantly higher percentage of water-soluble pectin than samples from Vernon or Kamloops.

Treatments of boron, manganese, magnesium, zinc, copper and calcium, either singly or in combination, failed to produce a significant effect on the water-soluble pectin content of tomatoes at Kelowna, Vernon or Kamloops, but the calcium treatments appeared to produce the most consistent increase in water-soluble pectin.

Increasing increments of superphosphate produced a significant progressive increase in the firmness of processed tomato samples at Vernon accompanied by a significant increase in tomato leaf phosphorus.

SUMMARY

The data obtained in this investigation suggest that firmness of B.C. Interior tomatoes may be affected by calcium, phosphorus and potassium levels in the soil. Calcium and phosphorus appeared to exert a beneficial effect on tomato firmness and high potassium levels appeared to be associated with lack of firmness.

Water-soluble pectin content appeared to be directly associated with firmness of tomato fruit and, therefore, it appears to offer some usefulness as an indicator of tomato firmness, but further investigation is required to determine its reliability as an accurate indicator of tomato firmness.

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