THE EFFECT OF SEVERAL TREATMENTS UPON THE INCIDENCE AND SEVERITY OF TOMATO FRUIT CRACKING AND BLOSSOM-END ROT

by

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ABSTRACT

Field experiments were conducted at the University of Manitoba in 1965 and 1966 to study the effect of a calcium foliar spray and soil salinity upon the incidence of tomato fruit cracking and blossom-end rot. In the second year, the effect of a manurial treatment also was studied. The calcium was applied as a 0.04M calcium chloride solution the first year and as a 0.06M calcium chloride solution the second year. Sodium chloride and sodium sulfate were used to increase soil salinity in 1965 while only sodium chloride was used in 1966.

The calcium chloride foliar sprays significantly reduced the incidence of blossom-end rot one year. No reductions in field cracking were recorded in 1965 but induced cracking was significantly less severe. In 1966 the incidence and severity of fruit cracking was reduced significantly in several of the spray treatments.

No definite conclusions could be drawn about the effect of the salinity treatments, but a reduction in fruit cracking was recorded in 1966.

In a greenhouse experiment designed to study the effect of varying calcium to magnesium ratios, increasing the calcium concentration decreased the incidence of blossom-end rot and the severity of fruit cracking.

The calcium content of the fruit was significantly and negatively correlated with fruit cracking. Highly significant correlations were obtained between the severity of concentric cracking and fruit calcium and between the incidence of radial cracking and fruit calcium. Increasing the calcium to magnesium ratio of the nutrient solution significantly increased the calcium content of the fruit, the importance of the magnesium concentration being secondary to the calcium concentration.

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Manitoba grown tomatoes are affected frequently by a high incidence of fruit cracking and blossom-end rot. The severity of these two diseases varies widely from year to year but fruit cracking is usually the more serious. Cracked fruits have a lower market value and are easily invaded by disease organisms. The lowered market value is especially pertinent in Manitoba where all the tomatoes grown are for the fresh market trade. While the incidence of blossom-end rot is less severe, fruits infected with this disease have no market value.

The initiation of fruit cracks occurs just prior to or shortly after the insipid stage of ripening. This forces market gardeners to harvest their tomatoes 2-3 weeks before ripening. The cost of this practice is high not only because of increased handling and storage but also because of the loss of size and weight due to the immaturity of the tomatoes.

Tomatoes constitute an important source of income for many market gardeners. In 1965, 2,835,000 pounds of tomatoes were produced in Manitoba for the fresh market trade. The farm value of the crop was $208,000.00 (98). In addition, many more thousands of pounds were grown in home gardens.

Manitoba is a potential producer of processing tomatoes. Canning companies already established in the province would have little difficulty incorporating tomatoes into their operations. Southern sections of the province have the land and climatic requirements and the potential irrigation facilities which could make mechanized tomato production feasible. Many drawbacks are unresolved, but the high incidence of blossom-end rot, and especially cracking, that occurs on the bush-type tomatoes presently grown poses a serious problem.

Research on tomato fruit cracking and blossom-end rot in Manitoba has been very limited. This study was initiated to investigate some of the causes of and possible control measures for these two disorders.

LITERATURE REVIEW

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FRUIT CRACKING

Tomato fruit cracking occurs in two basic forms, radial and concentric (18). Radial cracking involves cracks that radiate out from the stem-end of the fruit and vary considerably in depth. Concentric cracking involves cracks that extend more or less longitudinally around the shoulders of the fruit and are only skin deep.

Frazier (29) published one of the earliest reports on tomato fruit cracking. He observed that when detached fruits were immersed in a dye, the dye diffused into the fruit through the stem scar along lines that coincided with the area where the interlocular septae join the outer wall of the fruit. This was the same pattern that radial cracking followed. By the use of sectioning procedures, he reported a fission of the tissue lying directly above the locular division. He hypothesized that water follows a similar pathway upon entry into the fruit. Frazier and Bowers (32) predicted that any factor which increases the pressure of the locular contents of the fruit beyond a certain limit will cause the fruit to rupture at these weakened points in the cell wall.

Crack initiation and the severity of cracking usually increase with the ripeness of the fruit (63). Frazier (29) reported that the longer the fruit was on the vine, the more susceptible it was to cracking. Hepler (38) found that the greatest amount of induced cracking generally occurred at a maturity stage of about 6 days prior to the beginning of coloring. Frazier and Bowers (32) observed rather infrequent cracking of tomato fruits earlier than 12 days prior to the pink stage, and after a time when the highest daily increments of growth occur. Once a crack was initiated, though, lengthening proceeded easily.

The relationship between radial and concentric cracking has not been clearly defined. Frazier and Bowers (32) observed that severe concentric cracking did not seem to be related to weather conditions conducive to radial cracking. They reported that concentric cracking of greenhouse tomatoes was always low or non-existent.

Several scientists have associated water with cracking (31,32,61,100,63). Frazier (29) observed that heavily irrigated plots produced more cracking than plots left continually dry. He reported that rain, even a light shower, would induce cracking faster than irrigation. Brown and Price (9) reported that non-watered plots produced 20 percent fewer cracked fruits than watered plots. Moore, Kattan, and Fleming (62) showed that cracking was increased by a higher irrigation level and reduced by a closer spacing.

The beneficial effects of shading on reducing cracking have been reported (29,31,63,100). Frazier and Bowers (32) found that shading reduced the severity of cracking, but that it was relatively less effective in reducing radial cracking as compared to the concentric type. Brown and Price (9) reported that when plants were shaded with cheesecloth there was about a 10 percent reduction in cracked fruits. On the other hand, Hepler (38) found no differences between shaded and non-shaded fruits.

Pruning and staking of tomatoes has been reported to increase the severity of cracking, especially the incidence of concentric cracking (29). This may be due to the decrease in the amount of foliage cover for the fruits (31). Frazier (30) states, "Without a single exception, percentage of radial and concentric cracking was highest on fruits from pruned, staked vines".

Conflicting observations were reported by Brooks (8). He found that a modified pruning method whereby only the side shoots between the first and fourth cluster were removed, resulted in up to 60 percent less cracked fruits.

Frazier (30) found no appreciable differences due to fertilizers, although he reported that his results were extremely variable. Moore, Kattan, and Fleming (62) observed that high fertility increased cracking.

Several researchers have observed that varietal differences exist in susceptibility to cracking (29,31, 32,62,80,100). Uhlinger (89) speculated that there are two separate genetic systems for resistance to radial cracking. Under conditions of mild stress, resistance to cracking was observed to be dominant to susceptibility, while under conditions of severe stress, resistance was recessive to susceptibility. Resistance to concentric cracking appeared to be dominant to susceptibility under the conditions of Uhlinger's experiment.

Recent research on cracking has dealt with ways and means to evaluate the cracking resistance of breeding lines when extensive field cracking does not occur. Hepler (38) devised a method whereby the detached fruits were immersed in distilled water and placed under vacuum until all the air trapped in the stem scar had been withdrawn. This procedure allowed the water to enter the fruit freely. The fruits were allowed to remain immersed for a given period of time and then the severity of the induced cracks was recorded. Hepler reported that the crack induction results paralleled field observations taken on the same varieties over a period of years. Voisey and Lyall (91) used a puncture test method for evaluating crack resistance. They recorded significant differences between varieties tested. The varieties which exhibited the least resistance to puncture had the highest incidence of field cracking.

The beneficial effect of calcium on reducing cracking has been reported (16). Dickinson and McCollum (17), using

Hepler's method of crack induction, found that when $CaCl_2$ was added to the infiltrating solution, cracking was reduced significantly or prevented. NaCl or KCl did not control cracking. They further reported that a 0.04M $CaCl_2$ spray applied to the intact tomato plant gave a significant reduction in the length of induced cracks and a significant increase in the calcium content of the fruit when compared to the control.

A considerable amount of research has been reported relating cracking, firmness, and the calcium content of the fruit. Uhlinger (89) found a positive correlation between softness and cracking in the field ($r = 0.30$ to 0.50). A higher correlation of $r = 0.50$ to 0.80 was recorded between softness and cracking from external pressures. Rizk (74) observed that there was a good positive correlation between the calcium content of the fruit and firmness for tomatoes of the same maturity. Shafshak and Winsor (78) found that lime significantly increased the firmness of the fruit of one variety they tested.

Relationships between fruit firmness, cracking, chemical constituents and maturity have been noted. Frazier (29) suggested that cracking may be caused by the breakdown of protopectin as ripening advances. Rizk (74) reported a good positive correlation between alcohol insoluble solids, insoluble pectin, total pectic substances and the firmness of tomatoes. He found an excellent negative correlation between soluble pectin and firmness. Rizk observed that firmness correlated higher with insoluble pectin than with soluble pectin. El Sayed and Erickson (22) reported similar results. Hobson (41) found a significant negative correlation between fruit firmness and the units of polygalacturonase activity in tomatoes. Polygalacturonase had been identified previously as a pectic enzyme. Singh (80) reported a definite increase in soluble solids with advancing maturity. He found that a low concentration gradient of soluble solids, dry matter, and hydrogen ion concentration from the stem to the blossom-end was associated with increased radial cracking.

One of the first researchers to suggest the essential role of pectic materials in plant tissues was Baily (4). He reported,

> Pectic substances are the principle factors for structural integrity in fruits and vegetables. Plant cells are thought to be bound together in insoluble pectic compounds of the middle lamella and the softening of tissues is related to the degradation of these pectic materials.

The importance of calcium and pectic substances and their role in tomato firmness was demonstrated by Loconti and Kertesz (50). They showed that when peeled tomato fruits were first immersed in a dilute solution of $CaCl_2$, the amount of calcium pectate extracted from them was in all cases higher than from the control samples. The fruits were firmer also. The tomatoes lost their firmness upon immersion in ammonium citrate solution which dissolved the pectic substances. No firming occurred upon re-immersion in $CaCl_2$.

BLOSSOM-END ROT

Blossom-end rot is a physiological or non-parasitic disease (18). It first appears as a water-soaked spot near the blossom-end of the fruit. This spot becomes brown to black and enlarges until it may cover a third to half of the surface of the fruit. As it increases in size the tissues shrink; the surface of the spot becomes flattened or concave and dark and leathery. There is no soft-rotting of the fruit unless the spots are invaded by bacteria or fungi.

The tomato fruits are most commonly affected when a third to half grown, but they may be affected at any stage (18). Westerhout (93) reported that in vigorously growing plants the incipient stages of blossom-end rot occurred from 7 to 10 days after anthesis. Riggleman (73) observed a range of 10-24 days after anthesis in the varieties he tested.

The cause of blossom-end rot frequently has been attributed to an apparent water deficit in the plant. The water deficit is believed to result in an insufficient amount of water reaching the fruit, with the resultant collapse of the cells of the blossom-end (52,70,75,85). Experimental observations provided evidence that either irregularity in the water supply or low soil moisture increased the occurance of blossom-end rot (7,85). Riggleman (73) reported, "Irrigating when 50 percent of the available soil moisture was depleted consistently reduced the incidence of blossom-end rot".

The adverse effects of high salinity upon the occurance of blossom-end rot has been cited (34,35,42,77). Clay and Hudson (14) reported that blossom-end rot was induced by salinity. They found that adding potassium or magnesium sulfates to the soil increased the incidence of the rot. Robbins (75) demonstrated that when tomatoes were grown in nutrient solutions of increasing concentrations, the increase in the percentage of infected fruits paralleled the increasing concentrations. High solution concentrations and any other factors seriously restricting the water available to the fruit were interpreted by Robbins as favoring the development of the disorder.

Simple water relationships or water stress did not explain the occurence of blossom-end rot entirely. Brooks (7) reported that continued excessive watering may cause the disorder. Stout (85) observed that heavy infrequent waterings gave less blossom-end rot than light frequent waterings. The higher the incidence of blossom-end rot accompanying over-watering was attributed by Stout to the reduction in the size of the root system. Stout stated that similar results had been observed when tomato plants were staked and pruned. A higher incidence of blossom-end rot was accompanied by a restricted root system on the staked plants. High or low transpiration rates were reported by Foster (28) to have no effect on the incidence of the disorder.

The effect of competition (plant populations) has been noted. When moisture was limited, high plant populations were reported to increase the amount of the disease present (94). When moisture was not limited, high plant populations decreased the occurence of the disease (73).

Differences between varieties in their susceptibility to blossom-end rot have been observed (57,73,99). However, attempts to breed for resistance have not been successful (89).

Numerous reports on the effects of fertility levels and nutrient balance have been made. High levels of nitrogen frequently have been cited as contributing to the incidence of the disease (27,28,35,54,71,83,86). Brooks (8) reported that ammonical fertilizers in particular favor the development of the rot but that nitrate of soda tended to decrease it. Lyon, Beeson and Barrentine

(52) reported no correlation between the nitrate supply and the incidence of the rot. Raleigh and Chucka (71) concluded that balance between the elements was more important than actual concentration or the osmotic value of the nutrient solution.

Recent research has dealt mainly with the calcium nutrition of the plant and factors affecting the availability of calcium to the fruit. The importance of calcium was first suggested by Brooks (7) in 1914. He recommended that lime be used to decrease or check the rot. Foster (28) reported later that superphosphate, which contains gypsum ($CaSO_4$), had a marked effect in reducing the occurence of the disease. Raleigh (70) demonstrated that only in those solutions lacking calcium did typical blossom-end rot symptoms develop.

The first scientists to definitely implicate calcium deficiency with blossom-end rot were Lyon, Beeson and Barrentine (52). They studied the occurence of blossom-end rot in sand culture with a wide range of different nutrient solutions varying in the relative proportions of the macronutrients. Their results showed that the incidence of the rot was associated only with calcium deficiency. In treatments where the rot was most severe, the fruits were low in calcium and high in potassium and magnesium. Beeson, Lyon and Barrentine (5) reported that the calcium supply to the roots was significantly and positively correlated with the calcium content of the fruit. Further confirmation of the importance of calcium was given by McIlrath (58). He observed that visible signs of extreme calcium deficiency were evident during the stage of rapid fruit enlargement. Raleigh and Chucka (71) reported that any treatment which resulted in less than 0.20 percent calcium in the fruit (dry weight) increased the incidence of the disease.

Evans and Troxler (26) used field and greenhouse experiments to evaluate the effect of calcium fertilizers, calcium chloride sprays, and calcium gluconate injections into the fruit in the prevention of blossom-end rot. Only the calcium gluconate injections failed to reduce the rot significantly. Geraldson (34) confirmed the value of calcium fertilizers and calcium sprays in the prevention of blossom-end rot. Geraldson (35) concluded that a deficiency of calcium is the fundamental cause of blossom-end rot. He stated that soluble calcium salts in the soil may be deficient or excessive total salts may interfere with the calcium nutrition of the plant. Similar findings relating calcium deficiencies and blossom-end rot have been reported (14,57,73,79,83,86,89,93).

Spurr (82) made a detailed histopathological study of blossom-end rot with special reference to calcium nutrition. He found that the first signs of the disease were brown proteinaceous inclusions in the protoplasts of some of the epidermal cells at the distal end of the fruit. This was followed by disorganization of the protoplasts of the epidermal cells and collapse of some of the underlying cells of the pericarp. Depression of the fruit was noted to be due to the collapse of these cells. Cytoplasmic disorganization has been noted as one of the first significant features of calcium deficiency;collapse of the cell walls was secondary (55). Spurr suggested that a water deficit was not the primary cause of the disorder, but a calcium deficiency at the actively growing fruit tip.

CALCIUM AVAILABILITY

A deficiency of calcium in the tomato fruit previously has been reported as one of the primary causes of fruit cracking and blossom-end rot. A review of some of the factors reported as limiting or facilitating uptake and translocation to the fruit seems pertinent.

High concentrations of soluble salts in the root zone have been associated with reduced calcium uptake by several workers (14,33,34,35,48,71,73). Increasing salt concentrations have been noted as decreasing the effective concentrations of the divalent cations (e.g. Ca^{++}) relatively faster than the effective concentrations of the monovalent cations (e.g. K^{+} and Na^{+}). The reduced Ca^{++}

ion activity results in a lowered uptake of Ca^{++} by the plant, relative to the other cations (18,35).

High concentrations of certain individual ions have been demonstrated as decreasing calcium uptake and translocation. Some of these ions are: phosphate (10,12); potassium (5,15,35,49,60,67,68,76); magnesium (35,43,59, 60); sodium (13,35,60,68); and ammonium (13,35,88).

Several factors have been found to accelerate or facilitate calcium uptake and translocation. They are: copper (10); increasing temperature (12); increasing moisture levels (12,73); sodium (46,87); and high pH (2,68,86).

Calcium has been reported to be actively absorbed by the plant (23,25,51,96). Epstein and Leggett (24) found that calcium competed with strontium and barium for identical binding sites or reactive centers on the carriers but not with magnesium.

The clay lattice structure, the percentage base saturation by different minerals and the root cation exchange capacity have been noted as affecting the calcium absorption by the plant. Jarusov (44) found that calcium was more mobile at 50 percent saturation from a Ca-H clay than from a Ca-Mg clay and still more than from a Ca-NH_4 clay. Mehlich and Colwell (59) reported that for a montmorillonitic soil, increasing the percentage of magnesium saturation while holding the calcium constant tended to lower the calcium content of the leaves. The effect was especially significant at the lower levels of total cation exchange capacities. They also observed that calcium release was lowest in a montmorillonitic soil and the magnesium release the highest, as indicated by plant uptake. Mehlich and Colwell further reported that the calcium content of the plant was more directly related to the percentage base saturation than to the total amount of calcium present in montmorillonitic soils. Mehlich and Reed (60) found that increasing the percentage of potassium or magnesium decreased the calcium content of the plant. Marshall (56) established that the ease of exchange of the Ca^{++} ion against the H^{+} ion decreased more rapidly with successive removals from montmorillonitic clays than from kaolinitic clays. Below 70 percent saturation with calcium the montmorillonitic clays were characterized by an extremely low active fraction and by a high energy of absorption for the Ca^{++} ion. Singh and Moorthy (81) observed that the activity coefficient of exchangeable magnesium is higher than that of calcium. Osmond (66) reported that in the tomato, divalent cation uptake was saturated at relatively low concentrations.

Drake, Vengris and Colby (19) found that the exchange capacity of the root can affect the relative uptake of the ions. That the root cation-exchange capacity of the tomato is low for a dicotyledon was shown by Drake and Campbell (20). The cation exchange capacity of the tomato roots was found to be 34.6 milliequivalents (me.) per 100 grams compared to lettuce and carrot at 65.1 and 51.7 me. per 100 grams respectively. Wallace (92) reported that when available potassium was high and calcium was low, plants with low cation exchange capacity roots frequently suffered from calcium deficiencies.

The successful use of calcium foliar sprays for the control of blossom-end rot in tomatoes (18,26,34,79), blackheart in celery (33), and cracking of tomatoes (16, 17) has been reported. Research on optimum rates, pH, carriers and wetting agents has been meager (96). Calcium is known to be absorbed quickly by the leaf but it is not easily translocated (11,64,69,96). Increasing root temperatures have been shown to increase foliar applied calcium absorption much more than increasing air temperatures (69).

The extreme immobility and lack of translocation of calcium was shown by Brady (6). He demonstrated that when calcium was supplied to only half of the roots of the peanut plant, there was no translocation of calcium to the other half of the roots.

The research cited indicates that foliar applied calcium must enter the tomato through the skin of the fruit itself. There is evidence that this occurs. Yamada

(97) found that calcium permeated the isolated cuticle of the tomato faster than any of the other ions tested. Also, intake greatly exceeded loss.

MATERIALS AND METHODS

MATERIALS AND METHODS

In 1965, the effects of calcium foliar sprays and soil salinity upon tomato fruit cracking and blossom-end rot were studied. In 1966, a manurial treatment was added and in addition, a greenhouse experiment was conducted to study the effect of varying Ca^{++}:Mg^{++} ratios upon cracking and blossom-end rot.

In 1965, an indeterminate tomato variety, Queens, was used. Previous experience had shown this variety to be crack susceptible. In 1966, two highly recommended varieties were used in the field experiments, an indeterminant variety, Moreton Hybrid, and a determinant variety, Starfire. Moreton Hybrid was used for the greenhouse experiment as well.

The field experiments were conducted on the University plots, the soil of which was classified as a Fort Garry-Osborne clay (21). Varying amounts of calcium and magnesium carbonates may have been present in the soil, although this fact was not verified. Soil samples were taken from the plot areas and analyzed in the Provincial Soil Testing Laboratory, Department of Soil Science, University of Manitoba, for nitrate nitrogen, available phosphorous, exchangeable potassium, pH and conductivity. The modified Harper Method (36) was employed to determine the quantity of nitrate nitrogen and the bicarbonate (0.5N $NaHCO_3$) extraction solution, developed by Olsen _et al._ (65), was used to determine the available phosphorus. Exchangeable potassium was extracted with 1.0N ammonium acetate at pH 7.0 and determined by the Baird Atomic flame photometer. A 1:1 mixture of air dry soil and distilled water as outlined by Janke (45) was used to determine the pH and conductivity. In addition, the base exchange capacity and the exchangeable calcium and magnesium were ascertained as outlined by Atkinson _et al_.(3). This method involved leaching the soil with 1.0N ammonium acetate (NH_4OAc) adjusted to pH 7.0, removing the excess NH_4OAc with 95% ethyl alcohol and determining the amount of ammonia adsorbed by the soil to calculate the base exchange capacity. Exchangeable calcium and magnesium was determined from the amount of calcium and magnesium dissolved in the NH_4OAc leachate.

FIELD EXPERIMENTS

Experiment I (1965)

The experimental design was a randomized block with six treatments and five replicates. The six treatments were as follows:

(1) check;

(2) 0.04M calcium chloride ($CaCl_2$) foliar spray;

(3) 2178 pounds per acre of sodium chloride (NaCl);

(4) 2178 pounds per acre of NaCl plus a 0.04M $CaCl_2$ foliar spray;

(5) 3267 pounds per acre of sodium sulfate (Na_2SO_4);

(6) 3267 pounds per acre of Na_2SO_4 plus a 0.04M $CaCl_2$ foliar spray.

All plots received an application of 48 pounds of nitrogen (N) and 60 pounds of phosphate (P_2O) per acre.

An analysis of the soil prior to transplanting showed 268.9 pounds per acre of nitrate nitrogen to the 2 foot level, 14.0 parts per million (ppm.) of available phosphorus and 526.3 ppm. of exchangeable potassium. Phosphorus is the only major element which would not be considered very high (44). The pH and conductivity of the water extract were 7.51 and 0.44 mmhos./cm. respectively, indicating that the soil was slightly alkaline in reaction and very low in soluble salts. The total base exchange capacity was 47.71 me./100g. while exchangeable calcium and magnesium were 23.26 and 23.61 me/100g. respectively. Due to calcium and magnesium carbonates in the soil, the exchangeable Ca^{++} and Mg^{++} readings were probably high. All the preceeding values were a mean of 12 samples taken from different sites in the plot area.

The tomatoes were seeded in the greenhouse on April 26, "pricked out" on May 13 and transplanted to the field on June 9. All plants were hardened for one week prior to setting in the field. Dead or damaged plants were replaced as they appeared. The plants were pruned and tied to stakes 3 times.

The sodium chloride and sodium sulfate were broadcast and raked in on July 31. The calcium was applied as a 0.04

molar solution of calcium chloride ($CaCl_2$) along with a surfactant (Tween 20) using a hand directed, mechanically powered sprayer in 6 separate applications beginning August 11 and ending September 8. All fertilizer was applied by placing a half ounce of 16-20-0 analysis fertilizer 6 inches to the side of each plant and 2 inches deep.

Double row subplots with 5 plants per row were used. The plants were staggered in the rows, each plant being 18 inches apart within the row and a foot apart between the rows, for each subplot. The area allotted each plant was 4.25 square feet. The distance between subplots was 6 feet.

The fruits were picked just past the pink stage of ripeness, and all fruit, ripe and green, were harvested on September 10.

Experiment II (1966)

The experimental design consisted of two randomized blocks, one for each variety. The experimental area was laid out so that the two randomized blocks could be analysed as a single split-plot design in cases where possible differences between varieties were important. For each variety there were 6 treatments and 5 replicates. The six treatments were as follows:

(1) check;

(2) 0.06M calcium chloride ($CaCl_2$) foliar spray;

(3) 50,000 pounds per acre of rotted manure;

(4) 50,000 pounds per acre of rotted manure plus a 0.06M $CaCl_2$ foliar spray;

(5) 10,000 pounds per acre of sodium chloride ($NaCl$);

(6) 10,000 pounds per acre of $NaCl$ plus a 0.06M $CaCl_2$ foliar spray.

The tomatoes were seeded in the greenhouse on May 2, "pricked out" on May 17 and transplanted to the field on June 15 and 16. Transplant loss was severe, especially on the high salinity treatments, probably due to alternate periods of excessive temperatures and flooding. Dead or damaged plants were replaced until July 7. The Moreton Hybrid variety plants were pruned and tied to stakes 3 times.

Fruits were picked when pink colored until the final harvest date which was September 19.

The sodium chloride and manure were broadcast and raked in prior to transplanting and after the plants were established all plots were rotovated. The calcium was applied as a 0.06M solution of calcium chloride ($CaCl_2$) together with a surfactant, Tween 20, using a hand directed, mechanically powered sprayer in 8 separate applications beginning July 19 and ending September 7.

Three row subplots with 4 plants per row were used. Moreton Hybrid plants were planted 3 feet apart between the rows and 18 inches apart within the rows. The area allotted each plant was 4.5 square feet. Starfire plants were planted 3 feet apart within and between rows and the are allotted each plant was 9.0 square feet.

Experiment III (1966)

The experimental design was completely randomized with 6 treatments and 4 replicates. The treatments were:

(I) A complete nutrient solution with a Ca^{++}: Mg^{++} ratio of 5:5 per liter.

(II) Number (I) at half strength.

(III) A complete nutrient solution with a Ca^{++}:Mg^{++} ratio of 5:2 per liter.

(IV) Number (III) at half strength.

(V) A complete nutrient solution with a Ca^{++}:Mg^{++} ratio of 10:2 per liter.

(VI) Number (V) at half strength.

The chemical composition of solutions (I), (II), and (V) is shown in Table 1. Analytical grade chemicals were used to prepare the stock solutions.

Sodium chloride was added to solutions (I) and (II) to give equal osmotic effects in all solutions. Near the end of the experiment, the amount of phosphorous in the solutions was doubled and the amount of potassium increased by one sixth when it was observed that the plants were low in these elements.

Four week old tomato plants about 4-5 inches high were placed in half gallon ceramic crocks containing 1800 ml. of nutrient solution. The roots were suspended in the

TABLE 1. The concentration of nutrients used in the nutrient solutions of experiment III.*

Solution	(I)		(III)		(V)	
Ion	mmoles / liter	ppm.	mmoles / liter	ppm.	mmoles / liter	ppm.
Ca^{++}	2.50	100.20	2.50	100.20	5.00	200.40
Mg^{++}	2.50	60.80	1.00	24.32	1.00	24.32
Na^{+}	8.50	195.42	10.75	247.15	7.00	160.94
Cl^{-}	11.50	407.76	10.75	381.16	12.00	425.48
NO_3^{-}	7.50	465.06	7.50	465.06	7.50	465.06
$H_2PO_4^{-}$	0.50	48.00	0.50	48.00	0.50	48.00
SO_4^{--}	1.00	96.07	1.00	96.07	1.00	96.07
K^{+}	3.00	117.30	3.00	117.30	3.00	117.30
Total	37.00	1496.69	37.00	1485.34	37.00	1543.65

* In addition to the above, all nutrient solutions contained 5.0 ppm. of iron (chelated), 0.5 ppm. Boron, 0.5 ppm. manganese, 0.05 ppm. zinc, 0.02 ppm. copper and 0.01 ppm. molybdenum. (This proceedure per Hoagland and Arnon (40)).

solution by inserting the plants in a cross-slit made in a layer of polyfoam placed over the crocks. Support was obtained by tieing the plants with twine hung from overhead wires. The solutions were aerated constantly and changed every week for the first month and every 5 days thereafter. Supplementary light was supplied to give a daylight period of approximately 14 hours.

A completely randomized design was used with each plant representing a replicate. Plants were spaced 18 inches apart.

The experiment was initiated September 15 and discontinued December 23.

YIELD AND QUALITY EVALUATIONS

(a) Yield of Tomatoes

In experiment I yields were expressed as the total weight of all fruit harvested and as the total weight of marketable fruit. Marketable fruit included only those fruit that were classified as mature green, had good shape, were 2½ inches in diameter or greater (approximately 140 grams), and exhibited no symptoms of blossom-end rot.

No yields were recorded for experiments II and III but the percentage of fruit 150 grams or greater was recorded in experiment II.

(b) Blossom-end Rot

The percentage of diseased fruit was recorded in experiments I, II and III. The values were transformed for statistical analysis using the arcsin transformation in experiments I and III. The square root plus a half transformation was used in experiment II. All the values reported are from transformed data.

(c) Cracking

The percentage of fruits exhibiting cracking when harvested was recorded in all experiments. In experiment I the severity of laboratory induced cracking was observed and coded 1-5, with 1 for severe and 5 for crack free. A sample of 10 fruits was used. The method used was similar to that described by Hepler (38) and Dickinson and McCollum (17). The fruits were immersed in distilled water at 72-74°F and subjected to a vacuum until all the trapped air was removed from the stem scar and then allowed to remain in the water for a period of two hours.

In experiment II, the percentage of cracked fruits weighing 150 grams or greater was recorded also. In addition, the percentage of fruits exhibiting cracks totaling 6cm. or greater was recorded.

In experiment III, the only cracking observation used for statistical purposes was the total length of cracks per fruit. The values were averaged for each replicate.

The arcsin transformation was employed to analyse the data of experiments I and II. The square root of X

RESULTS AND DISCUSSION

cm. plus ½ was used for analysing experiment III. All values reported are from transformed data.

(d) Percentage Dry Matter and pH

The percentage dry matter and pH were determined in experiments II and III. The method consisted of mixing a random sample of 10 uniformly ripe fruit in a blender. One hundred grams of the puree was used for dry matter determinations, the remainder being saved for pH determinations. The material was dried for 24 hours in a conventional oven at 70°C and then in a vacuum oven at 70°C until a constant weight was reached.

(e) Ca^{++} and Mg^{++}

In experiments II and III, the calcium and magnesium content of the fruit was determined. Ten fruit samples from 4 replicates were used for Moreton Hybrid while 5 replicates were used for Starfire. The method employed was that outlined by the Perkin-Elmer Corporation (1). The dried material was wet ashed with nitric, perchloric, and sulfuric acids. The parts per million of calcium and magnesium were determined on a Perkin-Elmer 303 Atomic Absorption Spectrophotometer.

The statistical analysis and interpretation of results are based on methods described by Steel and Torrie (85).

RESULTS AND DISCUSSION

The effects of $CaCl_2$ foliar sprays and high soil salinity upon tomatoes were studied with special consideration of fruit cracking and blossom-end rot. A manurial soil treatment was added in one experiment and the effect of varying the calcium to magnesium ratio of the nutrient solution was studied in a greenhouse experiment.

EXPERIMENT I (1965)

No statistically significant differences between the various treatments were recorded for either total or marketable yields, although the spray treatments were found to reduce yields slightly (Table 2).

TABLE 2. The effect of sodium chloride and sodium sulfate soil treatments, and 6 calcium foliar sprays on total and marketable yields of tomatoes.

Treatment	Rate of application lb./ac.		Yields per plot (lb.)	
	NaCl	Na_2SO_4	Total	Marketable
Check	-	-	58.0	37.8
NaCl	2178	-	56.6	37.1
Na_2SO_4	-	3267	55.5	36.1
0.04M $CaCl_2$	-	-	52.2	31.4
NaCl+0.04M $CaCl_2$	2178	-	52.3	32.1
Na_2SO_4+0.04M $CaCl_2$	-	3267	52.6	32.0
			n.s.	n.s.

A possible reason for the lack of any apparent effect of the high salt treatments upon yield can be attributed to the amount of rainfall received after application. Only 0.56 inches of rain fell during the 25 day period following application. This all came in light showers and did not move the salts down into the root zone. Soil tests taken 3 weeks after application showed that the salts had not penetrated past the 6 inch level in the soil.

The calcium sprays reduced yields slightly. This trend agrees with the report of Clay and Hudson (14). They found that foliar sprays reduced marketable yields significantly in some years.

The effect of sodium chloride and sodium sulfate, alone and in combination with calcium foliar sprays, on the incidence of blossom-end rot is shown in Table 3.

TABLE 3. The effect of sodium chloride and sodium sulfate soil treatments, and 6 calcium foliar sprays upon the percentage of blossom-end rot.

Treatment	Rate of application lb./ac.		Blossom-end rot % of fruit affected*
	NaCl	Na_2SO_4	
NaCl	2178	-	26.52a**
Na_2SO_4	-	3267	26.66a
Check	-	-	26.10ab
0.04M $CaCl_2$	-	-	23.64bc
NaCl+0.04M $CaCl_2$	2178	-	23.16c
Na_2SO_4+0.04M $CaCl_2$	-	3267	22.54c

* All values shown are for the arcsin transformation of the raw data.

** Data not identified by the same letter (a,b) are significantly different at the 5% level (Duncan's Multiple Range Test).

Significant differences at the 5 percent level were found between two treatments receiving the calcium foliar sprays and the unsprayed treatments. The difference between the $CaCl_2$ treatment and the check was just short of the accepted level of significance, being significant at the 6 percent level. The reduction in blossom-end rot agrees with the research of other workers presented previously. The NaCl and Na_2SO_4 treatments responded similarly to the check treatments, as they did in yields.

There were no significant differences in the percentage of marketable size fruit exhibiting cracking, as indicated in Table 4, although slight reductions in cracking were observed for 2 of the 3 spray treatments. Not only was the incidence of cracking low but also the severity; the longest cracks measured only 2-3 cm. in length.

Because the incidence and severity of field cracking was low, a test was conducted using the crack induction method described by Hepler (38). It was hypothesized that significant differences between treatments might be present if the severity of cracking could be increased. These results are given in Table 5.

Significant differences at the 5 percent level were recorded between the sprayed and unsprayed treatments. These results agree with those of Dickinson and McCollum (17). Any effects due to the high salt treatments were not evident.

TABLE 4. The effect of sodium chloride and sodium sulfate soil treatments, and 6 calcium foliar sprays on the percentage of marketable size fruit exhibiting cracking.

Treatment	Rate of application lb./ac. $NaCl$	Na_2SO_4	% Cracked fruits
Check	-	-	31.52
0.04M $CaCl_2$	-	-	26.44
$NaCl$	2178	-	29.34
$NaCl$+0.04M $CaCl_2$	2178	-	26.44
Na_2SO_4	-	3267	27.42
Na_2SO_4+0.04M $CaCl_2$	-	3267	27.94
			n.s.

TABLE 5. The effect of $NaCl$ and Na_2SO_4 soil treatments and 6 calcium foliar sprays upon the severity of induced cracking.

Treatment	Rate of application lb./ac. $NaCl$	Na_2SO_4	Severity of Cracking*
Check	-	-	3.090 a
$NaCl$	2178	-	3.078 a
Na_2SO_4	-	3267	3.042 a
0.04M $CaCl_2$	-	-	3.762 b
$NaCl$+0.04M $CaCl_2$	2178	-	3.670 b
Na_2SO_4+0.04M $CaCl_2$	-	3267	3.604 b

* Lower numbers represent more severe cracking.

Larger differences were recorded between treatments than in the field results. A possible reason is that the crack induction tests were conducted more uniformly. Fruit of uniform size and ripeness probably lowered the variability of the test. The fruits used were collected after the last harvest and therefore had received the largest number of calcium sprays and the calcium content of these fruits was probably higher than that of many of the fruit recorded as having been cracked on the vine. The most logical explanation appears to be that the dry conditions in the field were not conducive to field cracking. The increased severity of the crack induction test caused real differences to be observed.

It must be remembered that these results are the visual observations of one person. Therefore, human error and bias could be another factor to consider. The strongest feature of the crack induction results is that they provide evidence to indicate that further research is warranted.

EXPERIMENT II (1966)

Soil samples were taken from all the plots after the last harvest and analysed. Differences in pH and conductivity between the manurial and check treatments were negligible indicating that the manure had been low in soluble salts (Table 6). The high salt treatment (NaCl) reduced the pH slightly and raised the conductivity to a level which would be classified as saline in the 0-6 inch depth. Samples from the 6-12 inch depth ranged in conductivity from 3.5 to 5.0 mmhos./cm., values which would be classified as slightly saline (45). Examination of a few samples in the 12-24 inch depth revealed conductivities of 1.5-3.0 mmhos./cm.

TABLE 6. The effect of manurial and sodium chloride soil treatments upon the pH and conductivity.

Treatment	Rate of Application lb./acre		pH	Cond. mmhos./cm.
	Manure	NaCl		
Check	-	-	7.61	0.75
Check	-	-	7.47	0.75
Manure	50,000	-	7.46	0.80
Manure	50,000	-	7.59	0.76
NaCl	-	10,000	7.04	8.00
NaCl	-	10,000	7.05	6.11

The manurial treatments significantly increased the amount of available phosphorus and exchangeable potassium as was expected, but no increase in nitrate nitrogen was recorded (Table 7) for several possible reasons. Leaching had probably removed most of the nitrates elaborated prior to application so that very little nitrate nitrogen was applied. The high moisture levels that prevailed during the summer probably created anaerobic conditions which inhibited nitrification. The breakdown of organic matter in Manitoba is usually slow as well, probably due to low soil temperature. That small amount of nitrate nitrogen released, possibly was leached down below the 12" sampling depth due to the high precipitation of the summer. Also, the soil samples were not immediately dried, but remained moist for a couple of days after they were taken so that differential drying could have caused unequal amounts of nitrates to be elaborated, contributing to the variability. The significantly higher nitrogen level in the NaCl treatments can be attributed to the limited growth which occurred in these plots.

TABLE 7. The effect of manurial and NaCl soil treatments on the level of nitrogen, phosphorus and potassium.

Treatment	Rate of Application lb./acre		NO_3-N 0-12" (lb.)	Avail. P (ppm.)	Exch. K (ppm.)
	Manure	NaCl			
Manure	50,000	-	47.0 b*	33.4 a*	565.8 a*
Manure	50,000	-	29.3 b	32.6 a	557.3 a
Check	-	-	48.2 b	14.0 b	511.4 b
NaCl	-	10,000	66.7 ab	15.9 b	481.9 bc
NaCl	-	10,000	94.1 a	15.6 b	481.7 bc
Check	-	-	26.9 bc	13.0 b	460.2 c

* Data not identified by the same letter (a.b.c) significant at the 5 percent level.

The results of total calcium determinations on a sample of fruit from each treatment showed that the calcium content of the treatments which received a foliar application of $CaCl_2$ was higher than that of the comparable treatments (Table 8). The difference between the $CaCl_2$ and the check treatments and the manure plus $CaCl_2$ and the manure treatments was significant for both varieties. The difference between the NaCl plus $CaCl_2$ and the NaCl treatments was significant in the variety Starfire only. Significant differences within the sprayed and unsprayed treatments occurred only once. The analysis of variance showed that the difference between varieties was highly significant.

TABLE 8. The effect of applications of manure and NaCl to the soil and 8 calcium foliar sprays upon the calcium content of the tomato fruit.

Treatment	Rate of Application lb./ac.		Total Ca content g./1000g. dry wt.	
	Manure	NaCl	Moreton Hybrid	Starfire
0.06M $CaCl_2$	-	-	1.80 a	2.15 a
Manure + 0.06M $CaCl_2$	50,000	-	1.78 ab	2.09 a
NaCl+0.06M $CaCl_2$	-	10,000	1.61 bc	2.01 ab
Check	-	-	1.53 c	1.93 bc
Manure	50,000	-	1.49 c	1.87 bc
NaCl	-	10,000	1.50 c	1.76 c

The most striking feature of the preceding results was the significant increase in the calcium content of the sprayed fruits. Similar results have been reported by other workers (17,34).

The fruit calcium of the high salinity treatments was found to be much lower than the comparable sprayed and unsprayed treatments. This was expected since high salinity and high sodium ion concentrations have been associated by a number of workers (13,14,33,34,35,46,60,68,71, 73) with a reduced calcium uptake.

The manurial treatments were slightly lower than the comparable check treatments in total calcium, although the results did not reach significance. This trend was due probably to the higher phosphorus and potassium levels. These elements have been reported to lower calcium uptake and translocation to the fruit (5,13,15,35,49,60,67,68,76).

The average weights of the ripe fruit harvested are shown in Table 9. The NaCl treatments produced the smallest fruit, the difference being significantly lower than the manurial treatments for both varieties and the check treatment for Moreton Hybrid.

This apparent salinity effect agrees with previous reports (14,72). No significant differences were recorded between any of the other treatments, however, the calcium foliar sprays reduced fruit weights slightly in most cases.

TABLE 9. The effect of manurial and NaCl soil treatments and 8 calcium chloride foliar sprays upon the average fruit weight.

Treatment	Rate of Application lb./acre		Average fruit wt.	
	Manure	NaCl	Moreton Hybrid	Starfire
Manure	50,000	-	196.8 a	198.9 a
Manure + 0.06M $CaCl_2$	50,000	-	186.9 a	190.2 a
Check	-	-	193.1 a	182.0 ab
0.06M $CaCl_2$	-	-	173.8 ab	182.6 ab
NaCl	-	10,000	157.9 b	163.2 b
NaCl + 0.06M $CaCl_2$	-	10,000	153.8 b	169.0 b

Sinclair and Brown (79) reported that a calcium foliar spray reduced marketable yields. Geraldson (35) and Dickinson and McCollum (17) found that burning of the leaves occurred when high rates of $CaCl_2$ foliar sprays were used. The reduction in yield reported by Sinclair and Brown was due probably to leaf burning. No burning was observed in this experiment, but the slight reduction in fruit size may have been due to reduced leaf assimilation. On the other hand, Kattan, Stark and Kramer (47) reported no significant decreases in yield using foliar sprays at similar rates as those used in this experiment.

A considerable amount of variation was introduced into the statistical analysis by the NaCl treatments. These treatments had fewer plants, were later maturing and a couple of plots were missing. These factors may have obscured some significant differences within the other treatments.

To study further the effect of manurial treatments and calcium foliar sprays upon fruit size, the percentage of fruit equal to or greater than 150 grams was calculated, not considering the high salinity treatments (Table 10). The value of 150 grams (approximately 5.3 ounces) was considered to be the lower limit of consumer fresh market acceptance since Manitoba consumers have shown a preference for tomatoes weighing approximately 7 ounces. The effect of the NaCl treatments were not considered because only half of the fruits were in this class, making the sample size small and variable.

TABLE 10. The effect of 25 tons of manure per acre and 8 calcium chloride sprays, applied alone and in combination, upon the percentage of fruit 150 grams or greater.

Treatment	Moreton Hybrid	Starfire
Manure	65.80 a	62.42 a
Check	60.65 ab	56.38 b
Manure + 0.06M $CaCl_2$	55.46 bc	56.94 b
0.06M $CaCl_2$	51.78 c	55.48 b

For Moreton Hybrid, the foliar sprays significantly reduced the percentage of fruit 150 grams or greater over that of the corresponding unsprayed treatment. For Starfire, the unsprayed manurial treatment had significantly more fruit greater than 150 grams than any of the other treatments. This effect of the $CaCl_2$ sprays upon reducing fruit weight was probably due to reduced leaf assimilation and agrees with the findings of Sinclair and Brown (79).

The incidence and severity of fruit cracking on the vine was high. The pruned and staked variety, Moreton Hybrid, had very little concentric cracking but a high incidence of radial cracking ranging up to 75 percent on some subplots. Conversely, the indeterminant variety, Starfire, had very little radial cracking but severe concentric cracking. The difference in the type of cracking between the two varieties was highly significant (Table 11).

TABLE 11. The percentage of tomato fruits exhibiting either concentric or radial cracking only.

Variety	Percentage of fruits concentrically cracked only	Percentage of fruits radially cracked only
Moreton Hybrid	9.35 a*	47.18 a*
Starfire	51.44 b	8.08 b

* All data not identified by the same letter (a,b) are significantly different at the 1 percent level.

Because of the high incidence of cracking, a second classification, the percentage of fruit exhibiting cracks with a total length of 6 cm. or greater, was created. A total of 6 cm. of cracks per fruit was arbitrarily chosen and considered to be the extreme limit of consumer acceptance. These values, along with the percentage of fruits cracked are presented in Table 12.

TABLE 12. The effect of 25 tons of manure and 5 tons of NaCl per acre applied to the soil and 8 $CaCl_2$ foliar sprays, applied alone and in combination with the soil treatments, upon the incidence of tomato fruit cracking.

Treatment	Moreton Hybrid % of fruits		Starfire % of fruits	
	cracked	cracked ≥6 cm.	cracked	cracked ≥ 6 cm.
Manure	70.7 a	33.9 a	71.5 a	54.1 a
Check	65.2 ab	31.2 ab	66.7 ab	44.5 b
Manure + 0.06M $CaCl_2$	59.8 b	24.5 abc	61.3 b	38.5 bc
0.06M $CaCl_2$	57.7 b	23.3 abc	59.5 bc	39.1 bc
NaCl	45.6 c	21.3 bc	51.3 c	31.2 c
NaCl + 0.06M $CaCl_2$	45.6 c	20.1 c	58.1 bc	35.6 c

The high salnity treatments (NaCl) had less cracking than the other treatments, the difference being significant for about half of the comparisons. These results were opposite to what had been expected. The lower calcium content of the fruit harvested from the NaCl treatments, previously presented, was expected to produce an increased incidence of cracking similar to the results reported by Dickinson and McCollum (17). Similarly, the $CaCl_2$ foliar sprays, which increased the calcium content of the fruit, had no effect upon fruit cracking in the NaCl treatments.

A possible reason for the reduced incidence and severity of cracking is that the high salinity may have decreased the water uptake of the fruits and thereby limited the stress upon the outer wall of the fruit. The results of the percentage dry matter determinations, Table 13, help substantiate this theory, as the NaCl treatments had the highest percentage dry matter values for each variety.

TABLE 13. The effect of manurial and NaCl soil treatments and 8 $CaCl_2$ foliar sprays, alone and in combination, upon the percentage dry matter of ripe tomato fruits.

Treatment	Rate of Application lb./acre		% Dry Matter	
	Manure	NaCl	Moreton Hybrid	Starfire
NaCl	-	10,000	6.07 a	5.81 a
NaCl+0.06M $CaCl_2$		10,000	5.85 ab	5.80 ab
Manure	50,000	-	5.90 ab	5.60 ab
Check	-	-	5.82 b	5.49 bc
Manure+0.06M $CaCl_2$	50,000	-	5.44 c	5.32 c
0.06M $CaCl_2$	-	-	5.48 c	5.31 c

Also, a slower growth rate caused by the salinity may have decreased the tendency for cracking to occur. Results previously presented in Table 9 showed that the average fruit weight was lower for the NaCl treatments. In addition, the absence of fluctuating moisture conditions during the experiment limited any severe stresses that may have occurred due to the high salinity. Furthermore, the smaller samples obtained from the high salinity treatments due to missing plants, missing plots and late maturity contributed to the variability of the experiment and made real differences harder to detect.

The $CaCl_2$ foliar sprays reduced the percentage dry matter of the fruit over that of the comparable unsprayed treatment, the difference being significant in some cases (Table 13). This finding agrees with the research of Dickinson and McCollum (17) and appears to be due to reduced leaf assimilation. The NaCl treatments increased the percentage dry matter content of the fruit, probably due to increased soil salinity. Similar results were reported by Winsor et al (95).

Examination of the cracking data after the disturbing influence of the NaCl treatments has been removed reveals some significant differences between the treatments (Table 14). In all cases, the manurial treatment exhibited the most severe cracking with significant differences between the manurial and check treatments being recorded twice, once in each variety. No significant differences were recorded between the calcium spray treatments. All the sprayed treatments exhibited less cracking than the unsprayed treatments, the difference being significant in some cases.

TABLE 14. The effects of 25 tons of manure per acre applied to the soil and 8 $CaCl_2$ foliar sprays, alone and in combination, upon the incidence and severity of tomato fruit cracking.

Treatment	Moreton Hybrid % of fruits		Starfire % of fruits	
	cracked	cracked ≳ 6 cm.	cracked	cracked ≳ 6 cm.
Manure	70.7 a	33.9 a	71.5 a	54.1 a
Check	65.2 b	31.2 a	66.7 ab	45.5 b
Manure + 0.06M $CaCl_2$	59.8 bc	24.5 a	61.3 bc	38.5 b
0.06M $CaCl_2$	57.7 c	23.3 a	59.5 c	39.1 b

Similar results were obtained when only fruit 150 grams or greater were considered (Table 15). No differences within the unsprayed or the sprayed treatments were recorded but differences between these treatments were sharply defined. Grouping the fruit by weight removed error which might have been introduced by small fruit.

An evaluation of all the cracking data indicates some important trends. In most cases the manurial treatment had the highest incidence and severity of cracking. The check treatment was the next highest, but significant differences between the check and the manurial treatments were recorded only twice. Similar relationships were observed between the manure plus $CaCl_2$ and the $CaCl_2$ treatments. These two were lower than the unsprayed treatments in all cases, the differences being statistically significant in a number of instances.

TABLE 15. The effect of manurial soil treatments and 8 $CaCl_2$ foliar sprays, alone and in combination, upon the incidence and severity of cracking of fruits 150 grams or greater.

Treatment	Moreton Hybrid % of fruits		Starfire % of fruit	
	cracked	cracked ≥ 6 cm.	cracked	cracked ≥ 6 cm.
Manure	72.9 a	35.7 a	76.0 a	60.5 a
Check	73.3 a	34.7 a	76.9 a	54.6 ab
0.06M $CaCl_2$	59.3 b	26.4 a	62.5 b	44.9 b
Manure + 0.06M $CaCl_2$	62.7 b	29.0 a	63.8 b	43.1 c

There are several possible reasons why the manurial treatments showed more fruit cracking. The higher soil fertility levels relative to the check probably contributed to the increased cracking as observed by Moore, Kattan and Fleming (62). High levels of available phosphorus, potassium and possibly ammonium nitrogen may have reduced calcium uptake as previously mentioned or, together with other factors such as improved aeration and water holding capacity, probably speeded up growth rates, making fruits more susceptible to cracking.

The use of a calcium foliar spray lowered the incidence and severity of cracking, agreeing with the research of Dickinson and McCollum (17). This was accompanied by higher levels of calcium in the fruit and, since foliar applied calcium is poorly translocated (64,96), the only mode of entry seems to be through the fruit skin. There is evidence that this does occur (97). Also, the calcium absorbed by the root may be translocated to the fruit in relatively larger amounts when the vegetative parts receive a calcium spray.

The incidence of blossom-end rot was very low (Table 16) and no statistically significant differences between any of the treatments were recorded, even though no diseased fruits were found on any of the spray treatments.

TABLE 16. The effect of manurial and NaCl soil treatments, alone and in combination with 8 $CaCl_2$ foliar sprays on the incidence of blossom-end rot.

Treatment	Percentage Blossom-end Rot	
	Moreton Hybrid	Starfire
Check	1.586	0.818
0.06M $CaCl_2$	0.707	0.707
Manure	1.330	1.287
Manure+0.06M $CaCl_2$	0.707	0.707
NaCl	1.171	0.707
NaCl+0.06M $CaCl_2$	0.707	0.672
	n.s.	n.s.

Moisture relationships appear to offer the only explanation for these results. The calcium content of the fruit was apparently low enough for blossom-end rot to occur as Raleigh and Chucka (71) reported that any treatment which lowered the calcium content of the fruit below 0.20 percent of the dry weight increases the chance of blossom-end rot occuring. During the course of the experiment there was no occasion when the moisture content of the soil was low, and the temperatures during the critical period of rapid fruit growth were not excessive. Because the soil moisture levels remained quite high and unfluctuating, it seems reasonable to assume that the low incidence of blossom-end rot was due more to environmental conditions than to any of the treatment effects.

Poor correlations between the percentage of cracked fruits and the calcium content were obtained when all treatments were included, but when the high salinity (NaCl) treatments were omitted, good correlations were found (Table 17). The disturbing influence of the high salinity treatments was expected since these treatments had been found to be lower in calcium content, yet exhibited less cracking than the other treatments. Any correlation which included all treatments would then be necessarily low.

The percentage of cracked fruits and the calcium content were shown to be negatively and significantly correlated when the high salinity treatments were excluded.

TABLE 17. Correlations between tomato fruit cracking and the calcium content.

Comparison	Treatments included	r	$100r^2$
Var. Moreton Hybrid			
Percent of cracked fruits vs. Ca content	All,	-0.127	1.61
	Minus NaCl treatments	-0.839**	69.92
Percent of fruits cracked ≥6cm. vs. Ca content	All,	-0.236	5.56
	Minus NaCl treatments	-0.564*	31.84
Var. Starfire			
Percent of cracked fruits vs. Ca content	All,	-0.150	2.25
	Minus NaCl treatments	-0.495*	24.48
Percent of fruits cracked ≥6cm. vs. Ca content	All,	-0.214	4.58
	Minus NaCl treatments	-0.818**	66.98

* Significant at the 5 percent level.
** Significant at the 1 percent level.

For Moreton Hybrid, the coefficient of determination ($100r^2$) indicated that variation in the calcium content of the fruit could account for 69.92 percent of all observed variability in the percentage of cracked fruits, and for 31.84 percent of all the observed variability in the percentage of fruits cracked 6 cm. or greater. For Starfire, the coefficient of determination for the percentage of cracked fruits and the percentage cracked 6 cm. or greater vs. the calcium content was 24.48 percent and 66.98 percent, respectively.

Some obvious conclusions can be drawn from the correlation data. The percentage of cracked fruits and their calcium content seem to be closely related when widely different treatments are not included in the correlation values. For tomato varieties where the main type of cracking is of the radial type, such as Moreton Hybrid, a correlation between the percentage of cracked fruit vs. the calcium content appears more useful than a correlation between the percentage of fruit cracked 6 cm. or greater vs. the calcium content. The initiation, rather than the length of fruit cracks, seems to be related to calcium content. The reverse situation appears true for the variety Starfire where concentric cracking predominates.

The $CaCl_2$ foliar sprays lowered the pH of the ripe fruit, in all instances, often significantly, over that of the comparable unsprayed treatment (Table 18). The addition of NaCl to the soil lowered the pH, similar to the salinity effects reported by Winser <u>et al</u> (95).

TABLE 18. The effect of manurial and NaCl soil treatments and 8 $CaCl_2$ foliar sprays, alone and in combination, upon the pH of ripe tomato fruit.

Treatment	Rate of Application: Manure	Rate of Application: NaCl	pH: Moreton Hybrid	pH: Starfire
Check	-	-	4.31 a	4.33 a
Manure	50,000	-	4.28 ab	4.30 ab
0.06M $CaCl_2$	-	-	4.26 b	4.27 bc
Manure+0.06M $CaCl_2$	50,000	-	4.25 b	4.26 c
NaCl	-	10,000	4.15 c	4.16 d
NaCl+0.06M $CaCl_2$	-	10,000	4.12 c	4.15 d

EXPERIMENT III (1966)

Blossom-end rot occurred in all treatments. Except for a few fruits from treatment I which developed the disease late in the season, all of the diseased fruits occurred within a period of less than a week. The majority of these fruits weighed between 30 and 50 grams.

Significant differences in the incidence of blossom-end rot occurred between some treatments, with treatment I having the highest percentage of infected fruits and treatment VI the lowest (Table 19). The stronger nutrient solution concentrations produced a higher percentage of diseased fruits than the lower concentrations, while increasing the Ca:Mg ratio decreased the incidence of the disease. These results are similar in trend to research previously reported (5,52,71,75), but drawing any definite conclusions from the data would not be recommended because of the high variability which occurred (C.V. = 40 percent).

The only treatment which showed significantly less fruit cracking was the low concentration solution with a 5:1 calcium to magnesium ratio (Table 20).

The trend of the results indicates that increasing the calcium concentration of the nutrient solution decreases the severity of fruit cracking while increasing the total nutrient solution increases the severity of cracking. Assuming that any treatment which increases the calcium content of the fruit

TABLE 19. The effect of varying Ca:Mg ratios and solution concentrations upon the occurence of blossom-end rot.

Treatment	Concentration in me./liter of solution		Percentage of Blossom-end rot
	Ca	Mg	
I	5.0	5.0	42.63 a
II	2.5	2.5	29.13 ab
III	5.0	2.0	32.55 ab
IV	2.5	1.0	10.10 cd
V	10.0	2.0	24.55 bc
VI	5.0	1.0	7.05 d

TABLE 20. The effect of varying Ca:Mg ratios and solution strength upon the severity of tomato fruit cracking.

Treatment	Soln. Strength mmoles /liter	Conc. in me./liter		Mean Crack Length per Tomato
		Ca	Mg	
I	37.0	5.0	5.0	2.034 a
II	18.5	2.5	2.5	1.746 a
III	37.0	5.0	2.0	2.024 a
IV	18.5	2.5	1.0	1.750 a
V	37.0	10.0	2.0	1.745 a
VI	18.5	5.0	1.0	1.081 b

will inhibit cracking, the trend reported was expected. Not only should relatively higher calcium levels in the nutrient solution raise the calcium content of the fruit (5,34,52,71) but also the higher nutrient solution concentrations will decrease calcium uptake (34,71).

The calcium content of the fruit from treatments V and VI with a Ca:Mg ratio of 5:1 me./liter respectively, was very significantly higher. The magnesium content of the fruit was reduced significantly as the Ca:Mg ratio was raised and as the solution concentration was lowered (Table 21).

TABLE 21. The effect of varying Ca:Mg ratios and solution strength upon the Ca and Mg content of the fruit.

Treatment	Conc. of soln. mmoles /l.	Conc. me./l.		g/1000g. dry wt.	
		Ca	Mg	Ca	Mg
I	37.0	5.0	5.0	0.823 a	1.465 a
II	18.5	2.5	2.5	0.845 a	1.375 b
III	37.0	5.0	2.0	0.938 a	1.375 b
IV	18.5	2.5	1.0	0.963 a	1.268 c
V	37.0	10.0	2.0	1.178 b	1.252 c
VI	18.5	5.0	1.0	1.210 b	1.180 d

To ascertain whether the calcium or magnesium content of the fruit was related in any way to the severity of cracking, correlations were calculated (Table 22). Total calcium was found to be negatively and significantly correlated with total crack length per fruit. Total magnesium was not found to be correlated to cracking. Variations in the calcium content of the fruit could account for approximately 50 percent of the observed variation in the severity of cracking.

TABLE 22. Correlations between the Ca and Mg content and crack length of the tomato

Comparison	r	$100r^2$
Ca content of fruit vs. crack length	-0.707**	49.93
Mg content of fruit vs. crack length	+0.174	

** Significant at the 1 percent level.

Because the calcium content was found to be correlated with the severity of cracking, multiple and partial regression coefficients were calculated to show the effect of the varying calcium and magnesium ratios in the nutrient solution upon the calcium content (Table 23). The two solution strengths were considered separately.

The highly significant multiple correlation coefficient values indicate that the calcium content of the fruit was related to the combined effect of the calcium and magnesium concentrations of the nutrient medium. Since the calcium and magnesium concentrations were not random, no attempt was made to determine whether or not significant differences existed between them. However, because the "r" value for calcium, holding magnesium constant, was higher than that for magnesium, holding calcium constant, an "F test" was conducted to determine if the Mg^{++} ion concentration in the nutrient medium gives information about the calcium content of the fruit which was not given by the Ca^{++} ion concentration. The "F tests" for both nutrient solution strengths were highly significant, indicating that the Mg^{++} ion concentration does influence the calcium content of the fruit. Since "r" was negative, the effect of increasing the magnesium concentration would be to lower the calcium content of the fruit.

TABLE 23. The results of a regression analysis with the $Ca(X_1)$ and $Mg(X_2)$ concentrations of the nutrient solution as the independent variables and the Ca content of the fruit (Y) as the dependent variable.

Treatments	Mult. Corr. Coef. Ry.12	Partial Regression Coef. ry 1.2	ry 2.1
I, II, V	0.912**	0.8275	-0.5768
II, IV, VI	0.813**	0.6803	-0.4033

** Significant at the 1 percent level.

The preceding results show that the fruit calcium was negatively correlated with the severity of cracking. Both the Ca^{++} and Mg^{++} ionic concentrations of the nutrient solution influenced the calcium content of the fruit, the calcium concentration being the most important. Previous research lends support to these results; Dickinson and McCollum (17) reported that those treatments exhibiting the most severe cracking had the lowest calcium content. Increasing the calcium concentration of the nutrient solution has been found to increase the calcium content of the fruit (5,34,52,57). There is evidence that raising the calcium to magnesium ratio in the nutrient solution increases the fruit calcium, especially at low solution concentrations (5,34,52,71) while increasing the total nutrient solution concentration tends to lower the calcium content of the fruit (71).

The high calcium to magnesium ratio solutions had the lowest dry matter content, being significantly different from the lowest calcium to magnesium ratio treatments (Table 24).

TABLE 24. The effect of varying Ca:Mg ratios and nutrient solution concentrations upon the percentage dry matter.

Treatment	Soln. Conc. mmoles. /l.	Conc. in me./l. Ca	Conc. in me./l. Mg	Percentage dry matter
I	37.0	5.0	5.0	6.66 a
II	18.5	2.5	2.5	6.68 a
III	37.0	5.0	2.0	6.36 ab
IV	18.5	2.5	1.0	6.38 ab
V	37.0	10.0	2.0	6.04 b
VI	18.5	5.0	1.0	6.12 b

A review of the three experiments shows a close relationship between the incidence of fruit cracking and blossom-end rot and the level of calcium nutrition. Increasing levels of salinity and magnesium were found to depress calcium uptake. This is supported by the research of other workers (5,14,33,34,35,43,47,52,71,73). A slight reduction in the calcium content of the fruit due to higher levels of phosphorus and potassium is indicated and previous research also supports this finding (5,10,12,15,35,49,67,68,76,83).

The soil used in these experiments was alkaline in reaction and non-saline. The clay lattice structure was mainly montmorillonitic with an exchangeable Ca:Mg base saturation in milliequivalents of approximately 1:1. While the soil contained approximately 23 me. of calcium per 100 grams as well as some free calcium carbonates, the magnesium content was equally as high. The magnesium content of the subsoil may be even relatively higher. In no instance then does the percent base saturation with calcium exceed 50 percent. The exchangeable potassium content was found to be high and a considerable quantity of fixed ammonium may have been present as well. Hinman (39) reported an average of over 4 me. of fixed ammonium per 100 grams of soil in some Saskatchewan areas with the heavier soils containing the most fixed ammonium. Some of the soils Hinman tested were similar to that used in these experiments, the predominate clay minerals being montmorillonite and illite.

The characteristics cited in the preceding paragraph have been reported previously as inhibiting calcium release from the base-exchange system of the soil and uptake or translocation by the plant. Calcium release from montmorillonitic soils has been found to be depressed by increasing the magnesium saturation (44,59,60), by increasing the ammonium saturation (44), and by increasing the potassium saturation (60). Whenever the calcium saturation of montmorillonitic soils was less than 70 percent, the energy of absorption of calcium by the clay was quite high, relative to the other clay types (55). Lyon, Buckman and Brady (52) suggest that in cases where the crop has a high calcium requirement, part of the soil should have approximately a 90 percent base saturation with calcium. The release of calcium has been observed to be lowest in montmorillonitic soils while magnesium release was the highest (59) and, thus, the magnesium may exhibit an antagonistic effect upon calcium absorption (35,43). High potassium levels may inhibit calcium uptake as well (5,15,35,49,67,68,76), as might the ammonium concentration (13,35,88).

Because of the importance of calcium in the prevention of fruit cracking and blossom-end rot, the soil characteristics cited, such as the montmorillonitic clay lattice structure, the low percentage of calcium saturation, and the high levels of magnesium and potassium probably contribute to the high incidence of these physiological disorders.

The relatively low cation exchange capacity reported for tomato plant roots (20) is probably quite important since the concentration of the monovalent cations was high, especially ammonium and potassium. Under these conditions, calcium ion absorption has been reported to be low (19). Furthermore, Osmond (66) reported that divalent cation uptake by the tomato roots was saturated at relatively low concentrations. Thus, keeping the levels of monovalent cations, such as potassium and ammonium, and divalent cations, such as magnesium, low, would appear to facilitate calcium uptake. The high incidence of tomato fruit cracking and blossom-end rot observed appears to be due primarily to the low availability of calcium to the plant roots caused by the clay structure of the soil, and particularly the low percentage saturation of the base exchange with calcium. High levels of magnesium, potassium, and possibly ammonium, apparently contribute to the low calcium release. Soil salinity or pH does not appear to be a problem, although the high pH may tie up some calcium as insoluble phosphate compounds. Moisture levels and temperature may have a secondary effect, but do not seem to be of primary importance.

The soil structure and the relative percentages of base saturation can not be economically altered. Any control measures for cracking and blossom-end rot on soils similar to that used in these experiments would involve applying supplementary calcium to the fruit by a foliar spray. This spray should be applied directly to the fruit because of the immobility of calcium. A reduction in yield may occur especially if a very concentrated spray is used. The use of fertilizers containing excessive amounts of ammonical nitrogen, phosphorus and potassium should be avoided.

The reduction in cracking and blossom-end rot attributed to the $CaCl_2$ foliar sprays was disappointing, compared to the results reported by previous workers (26,34). Dickinson and McCollum (17) observed a very significant reduction in the severity of induced cracking of those fruits which received a 0.04M $CaCl_2$ foliar spray, relative to the check. Sinclair and Brown (79) reported very significant reductions in the incidence of blossom-end rot using a 0.05M $CaCl_2$ foliar spray. The lower soil temperatures found in Manitoba soils relative to those in the eastern U.S.A. may have affected the results of these experiments. Phillips (69) reported an increasing rate of absorption of foliar applied radiocalcium as the root temperatures were increased from 7°C to 24°C, while air temperatures were found to be much less effective. Burning of the leaves with $CaCl_2$ solutions 0.04M or stronger has been reported (17,18) but this was not observed, even at a rate of 0.06M. Perhaps higher concentrations and more frequent applications could be employed to effect more control. Different carriers may also be more effective.

SUMMARY AND CONCLUSIONS

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The use of calcium chloride foliar sprays provided some control of tomato fruit cracking and blossom-end rot. In 1965 the sprays afforded a reduction in the severity of laboratory induced cracking but no reduction in the incidence of field cracking was recorded. A decrease in the incidence of both radial and concentric field cracking was obtained in 1966. Better results were recorded in that year probably because the number of spray applications were increased from 6 to 8 and the calcium chloride concentration was raised from 0.04M to 0.06M. The sprays lowered the incidence of blossom-end rot in 1965 and, while no fruit where infected in 1966, the difference was not significant. The lack of a statistically significant control in 1966 was due to the low incidence of the disease in all treatments, probably because of the high soil moisture levels which prevailed throughout the entire season. A slight drop in yield and fruit size was recorded on the spray treatments but these reductions were not significant. Calcium chloride sprays appear to offer a means of reducing the incidence and severity of fruit cracking and blossom-end rot, but more frequent and concentrated sprays should perhaps be tried to afford increased protection.

No differences in the incidence of tomato fruit cracking and blossom-end rot were recorded in 1965 when an attempt was made to increase the soil salinity by the application of

2178 pounds per acre of sodium chloride or 3267 pounds per acre of sodium sulfate. In 1966, sodium chloride applied at 10,000 pounds per acre caused some significant reductions in fruit cracking compared to the check, but did not affect the incidence of blossom-end rot. These attempts at increasing the soil salinity were relatively unsuccessful in both years. In 1965 the salt was applied after the plants were established and did not penetrate far enough into the soil to affect the plants. In 1966 the salt was applied prior to transplanting and due to high precipitation and extreme temperatures immediately following, a number of plants were killed and others were set back severely. Any attempts to draw definite conclusions about the effect of salinity upon cracking and blossom-end rot are therefore not recommended.

The manurial treatment which was added in 1966 produced a consistently higher incidence and severity of fruit cracking than the check treatment in both varieties tested, although the increases were significant for only one comparison. This increase was attributed to the higher soil fertility levels created. No differences in the occurance of blossom-end rot were recorded.

In experiment III, increasing the calcium concentration of the nutrient solution was found to decrease the incidence of blossom-end rot and the severity of cracking, the differences being significant for some comparisons.

Decreasing the magnesium concentration had a similar, though less pronounced effect.

Analysis of the fruit from Experiments II and III revealed that the calcium content of the fruit was negatively correlated with the incidence and severity of cracking while magnesium was not. In experiment II, the calcium chloride foliar sprays increased the calcium content of the fruit while the high salinity treatment slightly reduced the calcium content. The manurial treatments appeared to have a depressing effect upon the calcium content. Higher concentrations of calcium in the nutrient solution increased the fruit calcium in experiment III, while raising the total solution concentration 2-fold reduced the calcium content slightly. The magnesium concentration of the nutrient solution was negatively correlated with fruit calcium but was of less importance than the calcium concentration.

In experiment II, concentric cracking predominated on the determinant variety, Starfire, while radial cracking was the dominant type on the indeterminant variety, Moreton Hybrid. The severity, rather than the incidence of concentric cracking, produced a higher correlation with fruit calcium. Conversely, the incidence of radial cracking, rather than the severity, gave a higher correlation with the calcium content of the fruit.

The high incidence of fruit cracking and blossom-end rot that occurs under local conditions is considered to be due to factors which depress the uptake of calcium from the soil. The most important factors appear to be the clay lattice structure of the soil, relatively high levels of potassium and magnesium saturation on the base exchange and the subsequent low percentage saturation of calcium. Since soils vary considerably within the Province of Manitoba, those soils with the highest saturation of calcium on the base exchange may be the best suited for tomato production. Results of this research indicate that it would be advantageous for Manitoba growers to provide supplemental calcium to tomato plants by means of a calcium foliar spray.

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APPENDIX

TABLE I. Analysis of variance for the effect of sodium chloride and sodium sulfate soil treatments and 6 calcium foliar sprays on total and marketable yields.

Source of Variance	D.F.	Total Yield M.S.	Marketable Yield M.S.
Replicates	4	3.970	3.498
Treatments	5	31.678	41.570
Error	20	21.266	26.459
Total	29		
C.V.		8.45%	14.95%

TABLE II. Analysis of variance for the effect of sodium chloride and sodium sulfate soil treatments and 6 calcium foliar sprays on the percentage of blossom-end rot.

Source of Variance	D.F.	M.S.
Replicates	4	7.243
Treatments	5	17.244**
Error	20	3.866
Total	29	
C.V.		8.06%

** 1.00% level of significance.

TABLE III. The analysis of variance for the effect of sodium chloride and sodium sulfate soil treatments and 6 calcium foliar sprays on the percentage of marketable size fruit exhibiting cracking.

Source of Variance	D.F.	M.S.
Replicates	4	128.960**
Treatments	5	19.194
Error	20	10.036
Total	29	
C.V.		11.24%

TABLE IV. Analysis of variance for the effect of sodium chloride and sodium sulfate soil treatments and 6 calcium foliar sprays upon the severity of induced cracking.

Source of Variance	D.F.	M.S.
Replicates	4	0.231
Treatments	5	0.589**
Error	20	0.101
Total	29	
C.V.		9.41%

TABLE V. Analysis of variance for the effect of manurial and sodium chloride soil treatments on the levels of nitrogen, phosphorus and potassium.

Source of Variance	D.F.	NO_3-N M.S.	Avail. P. M.S.	Exch. K M.S.
Replicates	9	5,170.69**	97.92*	4,160.79
Treatments	5	6,354.73**	946.07**	18,845.80**
Error	45	1,369.10	40.74	2,123.20
Total	59			
C.V.		71.06%	30.95%	9.04%

* 5.00% level of significance.

TABLE VI. Analysis of variance for the effect of applications of manure and sodium chloride to the soil and 8 calcium foliar sprays upon the calcium content of the fruit.

Source of Variance	D.F.	M.S.
Replications	3	0.058*
Varieties	1	1.456**
Error (a)	3	0.005
Treatments	5	0.155**
Var. X Treat.	5	0.006
Error (b)	29	0.017
Total	46	
C.V.		7.22%

TABLE VII. Analysis of variance for the effect of manurial and sodium chloride soil treatments and 8 calcium chloride foliar sprays upon the average fruit weight.

Source of Variance	D.F.	M.S. Moreton Hybrid	M.S. Starfire
Replicates	4	1597.45**	86.52
Treatments	5	2373.36**	1322.71**
Error	19	312.59	195.94
Total	28		
C.V.		10.00%	7.74%

TABLE VIII. Analysis of variance for the effect of 25 tons of manure and 8 calcium chloride sprays, applied alone and in combination upon the percentage of fruit 150 grams or greater.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	159.28*	10.15
Treatments	3	187.06*	49.14*
Error	12	36.94	13.09
Total	19		
C.V.		10.41%	6.26%

TABLE IX. Analysis of variance for the percentage of tomato fruits exhibiting either concentric or radial cracking only.

Source of Variance	D.F.	Concentric M.S.	Radial M.S.
Main Plots	9		
Replicates	4	37.56	36.01
Varieties	1	26,581.94**	22,932.15**
Error (a)	4	75.85	93.37
Treatments	5	277.49**	28.12
Var.X Treat.	5	158.10*	171.13**
Error (b)	47	46.75	49.52
Total	57		
C.V.			

TABLE X. Analysis of variance for the effect of 25 tons of manure and 5 tons of sodium chloride per acre applied to the soil and 8 calcium chloride foliar sprays applied alone and in combination with the soil treatments, upon the incidence of tomato fruit cracking.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	216.09*	47.09
Treatments	5	523.22**	246.83**
Error	19	52.66	41.96
Total	28		
C.V.		12.64%	10.55%

TABLE XI. Analysis of variance for the effect of 25 tons of manure and 5 tons of sodium chloride per acre and 8 calcium chloride foliar sprays, applied alone and in combination with the soil treatments, upon the severity of tomato fruit cracking.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	130.42	43.55
Treatments	5	152.37*	317.83**
Error	19	54.64	34.37
Total	28		
C.V.		28.80%	14.47%

TABLE XII. Analysis of variance for the effect of 25 tons of manure per acre and 8 calcium chloride foliar sprays, alone and in combination, upon the incidence of tomato fruit cracking.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	105.20**	34.01
Treatments	3	160.36**	147.94**
Error	12	16.17	17.78
Total	19		
C.V.		6.35%	6.51%

TABLE XIII. Analysis of variance for the effect of 25 tons of manure per acre and 8 calcium chloride foliar sprays, alone and in combination, upon the severity of tomato fruit cracking.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	40.79	139.05
Treatments	3	128.04	258.06**
Error	12	47.73	41.31
Total	19		
C.V.		24.53%	14.57%

TABLE XIV. Analysis of variance for the effect of manurial and sodium chloride soil treatments and 8 calcium chloride foliar sprays upon the percentage dry matter of ripe tomato fruits.

Source of Variance	D.F.	M.S.
Main Plots	7	
Replicates	3	0.048
Varieties	1	0.587
Error (a)	3	0.065
Treatments	5	0.392**
Var.X Treat.	5	0.015
Error (b)	30	0.028
Total	47	
C.V.		2.94%

TABLE XV. Analysis of variance for the effect of manurial soil treatments and calcium chloride foliar sprays upon the incidence of cracking of fruits 150 grams or greater.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	166.20**	36.61
Treatments	3	254.04**	299.07**
Error	12	26.58	24.14
Total	19		
C.V.		7.69%	7.04%

TABLE XVI. Analysis of variance for the effect of manurial soil treatments and calcium chloride foliar sprays upon the severity of cracking of fruits 150 grams or greater.

Source of Variance	D.F.	Moreton Hybrid M.S.	Starfire M.S.
Replicates	4	67.36	12.80
Treatments	3	100.79	337.73**
Error	12	46.40	54.73
Total	19		
C.V.		21.67%	14.57%

TABLE XVII. Analysis of variance for the effect of manurial and sodium chloride soil treatments and 8 calcium chloride foliar sprays upon the incidence of blossom-end rot.

Source of Variance	D.F.	M.S.
Main Plots	9	
Replicates	4	0.935
Varieties	1	1.040
Error (a)	4	0.178
Treatments	5	0.748
Var.X Treat.	5	0.196
Error (b)	47	0.363
Total	57	
C.V.		6.51%

TABLE XVIII. Analysis of variance for the effect of manurial and sodium chloride soil treatments and 8 calcium chloride foliar sprays upon the pH of ripe tomato fruit of Experiment II.

Source of Variance	D.F.	M.S.
Main Plots	7	
Replicates	3	0.007
Varieties	1	0.004
Error (a)	3	0.001
Treatments	5	0.046**
Var.XTreat.	5	0.0002
Error (b)	30	0.0006
Total	47	
C.V.		0.58%

TABLE XIX. Analysis of variance for the effect of varying Ca:Mg ratios and solution concentrations upon the occurance of blossom-end rot.

Source of Variance	D.F.	M.S.
Treatments	5.	741.13**
Error	18	95.65
Total	23	
C.V.		40.19%

TABLE XX. Analysis of variance for the effect of varying Ca:Mg ratios and solution concentrations upon the severity of tomato fruit cracking.

Source of Variance	D.F.	M.S.
Treatments	5	0.481**
Error	18	0.084
Total	23	
C.V.		16.68%

TABLE XXI. Analysis of variance for the effect of varying Ca:Mg ratios and solution strength upon the calcium and magnesium content of the fruit.

Source of Variance	D.F.	Calcium M.S.	Magnesium M.S.
Treatments	5	0.109**	0.055**
Error	18	0.011	0.003
Total	23		
C.V.		10.49%	4.35%

TABLE XXII. Multiple regression analysis with nutrient solution calcium and magnesium concentrations as the independent variables and the calcium content of the fruit as the dependent variable.

Source of Variation	D.F.	I, III and V M.S.	II, IV and VI M.S.
Regression	2	0.1312**	0.1389**
Error	9	0.0058	0.0158
Total	11		

TABLE XXIII. Analysis of variance for the effect of varying Ca:Mg ratios and nutrient solution concentration upon the percentage dry matter.

Source of Variance	D.F.	M.S.
Treatments	5	0.277
Error	18	0.103
Total	23	
C.V.		5.03%