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Effect of calcium on yield and incidence of fruit disorders in three tomato cultivars

Muhammad Syamsoel Hadi

To the Graduate Council:

I am submitting herewith a thesis written by Muhammad Syamsoel Hadi entitled "Effect of calcium on yield and incidence of fruit disorders in three tomato cultivars." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Carl E. Sams, Major Professor

We have read this thesis and recommend its acceptance:

Dennis E. Deyton, David L. Coffey

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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EFFECT OF CALCIUM ON YIELD AND INCIDENCE OF FRUIT DISORDERS IN THREE TOMATO CULTIVARS

A Thesis
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Degree
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Abstract

Greenhouse experiments were conducted in Fall 1995 (1 experiment) and Spring 1996 (2 experiments), which will be referred to as "Experiment 1", "Experiment 2", and "Experiment 3", respectively. Three levels of calcium (low = 20 ppm; medium = 220 ppm; and high = 1,020 ppm; that represented very deficient, normal, and near toxic levels of calcium) were applied to three cultivars of tomato ('Mountain Supreme', 'Celebrity', and 'Sunrise'; selected to represent genetic differences in susceptibility to blossom-end rot (BER)) grown in modified Hoagland solutions utilizing a greenhouse hydroponic system. The source of basic nutrients was a 5-11-26 soluble fertilizer containing micronutrients. The ratio of N-P-K was adjusted to 1.0 : 0.6 : 2.5 by adding NH_4NO_3 (34% N). Calcium was added as $CaCl_2 \cdot 2H_2O$. In experiment 1 leaf samples were collected below the 1st, 3rd, and 5th flower clusters. Leaf samples for experiments 2 and 3 were collected above the 1st and 5th flower cluster. Both leaf and fruit calcium contents were analyzed by inductively coupled plasma emission spectrophotometry (ICP). Tomato fruits were harvested 2 or 3 times a week at the breaker stage. Total yield was measured as fruit weight, and marketable fruits were determined based on fruit size and the absence of physiological disorders. Fruits with a diameter > 6.3 cm and free from BER and cracking were categorized as marketable. Leaf and fruit calcium concentrations were increased by the medium calcium treatment. Leaf calcium concentration did not significantly differ among the tomato cultivars studied. Fruit calcium concentration responses of the three cultivars were different between Fall and Spring experiments. In experiment 1 (Fall 1995), across treatments 'Mountain Supreme' had a

higher fruit calcium concentration than 'Celebrity'. No significant differences in fruit calcium occured in experiments 2 and 3 (Spring 1996). In all the experiments conducted, the medium calcium treatment reduced the incidence of BER. The total weight of marketable fruit was not affected by the medium calcium treatment in experiment 1, but it was increased by the medium calcium treatment in experiments 2 and 3. In all three experiments the high calcium treatment reduced the total fruit weight per plant, average fruit weight, total weight of marketable fruit per plant, and average marketable fruit weight. 'Celebrity', across treatments, was consistently more susceptible than 'Mountain Supreme' to incidence of fruit disorders.

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Chapter 1

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is widely grown in the world and commonly consumed because of its nutrient content, as well as its taste, flavor, and appearance. Therefore, it is well established that tomatoes are an important source of nutrients in the human diet, especially in developed countries, e.g. ranked first among vegetables in the U.S.A. (Rick, 1978).

One important factor influencing tomato appearance is the existence of either physical or physiological fruit disorders. Fruit disorders result in unmarketable tomatoes, and reduce growers' income. Increased attention has been given to using calcium to correct soil acidity problems in crop production as a result of more intensive use of acidifying fertilizers, however little attention has been given to calcium itself as a nutrient (Millaway and Wiersholm, 1979).

Fruit disorders such as blossom end rot (BER) and cracking have long been recognized as physiological disorders associated with calcium (Ca) deficiency, although this association is not always consistent (Shear, 1975). Other factors that influence the incidence of fruit disorders are environment (relative humidity, irradiance, and temperature) and genetic susceptibility (Adams and Ho, 1992), as well as, nutritional imbalance in fertilizer solutions (Leatherland, 1990).

The results of experiments conducted on the effects of calcium on fruit disorders are still controversial, even though most researchers are convinced that Ca can reduce physiological disorders. Variation in results may be caused by the level of Ca treatments, the method of Ca application, and genetic differences among cultivars in calcium utilization.

It is possible that different cultivars have different Ca uptake efficiencies. Soliman and Doss (1992) suggested that there was a difference in physiological response between two tomato cultivars tested in accumulation of calcium. However, Ho *et. al.* (1993) reported that high temperature was the major factor which induced BER, regardless of cultivar or salinity.

The effects of magnesium (Mg), potassium (K), nitrogen (N), and boron (B) on Ca uptake and the incidence of BER have been investigated separately (Bar-Tal and Pressman, 1996; Di Candilo and Silvestri, 1994; Hohjo *et al.*, 1995). Results from experiments investigating the effects of Ca on physiological disorders of tomato fruit have not been conclusive.

The objectives of this research were to: 1) investigate the role of Ca in yield and incidence of fruit disorders of tomatoes, and 2) determine cultivar variation in calcium uptake and/or partitioning.

Chapter 2

Literature Review

Role of calcium in tomato fruit quality

Calcium (Ca) accumulates in older tissue since it is immobile once deposited within the plant. Therefore, Ca deficiency often occurs in newer tissues such as fruits (Millaway and Wiersholm, 1979). The role of Ca in tomato fruit quality is related to the existence of Ca in fruit structures. Calcium is largely stored in the endoplasmic reticulum, mitochondria, vacuole, chloroplast, and cell wall (Poovaiah, 1988). More specifically, the results of an experiment conducted by Burns and Pressey (1987) indicated that increased amounts of Ca^{2+} are bound to the cell wall-middle lamella of tomato pericarp as ripening occurs. The principal function of Ca^{2+} in cell wall structure is the cross-linking of pectic polymers, mainly in the middle lamella (Ferguson, 1984). In the cell wall, the existence of Ca ions (1-5mM) is essential for protecting the plasma membrane, maintaining the structural integrity of the cell wall (Poovaiah, 1988), and conferring rigidity to the cell wall (Poovaiah, 1993).

Calcium may also play a role in fruit ripening. According to Rigney and Wills (1981), calcium movement may be a primary stimulus to the onset of the ripening process, with the action of polygalacturonase (PG) and ethylene being secondary control stages.

The importance of Ca in maintaining tomato quality has been investigated by many researchers (Adams and Ho, 1993; Di Candilo and Silvestri, 1994; Hohjo *et al.*, 1995; Oyewole and Aduayi, 1992). Research in the past two decades has clearly shown that increasing Ca^{2+} in various organs reduced the incidence and severity of various physiological disorders (Poovaiah, 1993). Fruit quality is reduced by the incidence of fruit disorders such as BER and cracking. Poovaiah (1985), Shear (1975), and English and Maynard (1978) cited that BER is related to Ca content of tissues. Most recent research reports support this relationship between BER and Ca. Bar-Tal and Pressman (1996) found that the incidence of BER-affected fruit was a function of the K/Ca ratio in the nutrient solution. However, Di Candilo and Silvestri (1994) reported that there was no effect of Ca on BER, and Nonami *et al.*, (1995) indicated that Ca deficiency may not be the direct cause of BER in tomato fruit.

Optimal calcium nutrition has also been implicated in preventing fruit cracking (Shear, 1975; Millaway and Wiersholm, 1979; Peet, 1992), which can also be caused by thin skin (Peet, 1992). Ca deficiency can lead to improper lignification, thus inhibiting cell wall thickening (Millaway and Wiersholm, 1979).

Partitioning of calcium

The role of Ca in influencing quality is limited most by Ca uptake and distribution into the fruit. The distribution of Ca in tomato fruit is uneven; the concentration in dry matter is highest near the calyx and lower at the distal (blossom) end (Adams, 1992). In addition, Adams and Ho (1992) reported that the lowest concentration of Ca was found in the placental and locular tissues. They stated that this localized deficiency is caused by a lack of coordination between cell enlargement in the distal placental tissue and the transport of Ca, via both the xylem and intercellular movement, towards the susceptible tissues in the distal parts of the locules and placenta. Xylem tissue development in the distal fruit tissue may be the anatomical basis for the initial Ca deficiency symptom of BER in the distal placenta. Calcium movement in the xylem is substantially retarded in high salinity (Belda and Ho, 1993). Fruit age also influenced the fruit Ca content as reported by El-Gizawy *et al.* (1986). They reported that the percentage of Ca in fruit (dry matter basis) declined markedly between 11 - 22 days after anthesis which may explain why the young fruit are very susceptible to BER. Sonneveld and Voogt (1991) found the decrease of fruit Ca occurred 7 - 10 days after anthesis, explaining that tomato fruit were most sensitive to Ca deficiency in this period.

Other factors such as salinity, other major nutrients, and environment can also affect the distribution of Ca and, thus, influence the incidence of BER. Adams and Ho (1993) reported that a very high incidence of BER was induced when salinity was increased. A low calcium level and a high concentration of free acids in the affected tissues were also observed. In contrast, Ho and Adams (1994) reported that increasing salinity to 15 mS cm^{-1} had no effect on partitioning even though this condition reduced the tomato plant dry weight. Bar-Tal and Pressman (1996) found that the incidence of BER correlated well with the K/Ca concentration in the leaves, but not in ripe fruit. English and Barker (1982) speculated that K^+ and Mg^{++} compete with Ca^{++} for functional sites in inefficient strains of tomato and displace Ca^{++} from metabolic roles, bringing about deficiency symptoms and lesser growth.

A recent study conducted by Di Candilo and Silvestri (1994) showed that a nitrogen treatment of 120 kg/ha can increase accumulation of Ca in fruits from 89 to 101 ppm, compared to a nitrogen treatment of 0 kg/ha. Nukaya *et al.* (1991) suggested that Cl concentration in the root environment influences Ca uptake.

Temperature also affects Ca distribution into fruit. Starck *et al.* (1994) reported a much higher portion of ^{45}Ca was transported to the fruit in a heat stress environment. Adams and Ho (1993) reported that root temperatures also influence Ca uptake. They found that a root temperature between 14° and 26°C increased Ca uptake as well as water uptake, compared to that recorded at lower or a higher temperatures.

Day-night periodicity was reported to affect Ca import by tomato fruit. The import of Ca by tomato fruit was higher at night than during the day (Tachibana, 1991) but the uptake of ^{45}Ca by tomato plants was greater during the day (Ho, 1990). The latter researcher mentioned that at night, due to low transpiration, less ^{45}Ca is transported to mature leaves but more to the fruit, while a great proportion of ^{45}Ca was retained in the stem.

Genetic resistance of tomato to fruit disorders

The efficiency of Ca utilization in tomato is a heritable attribute and some cultivars are more efficient than others (Kalloo, 1991). Ho *et al.* (1993) cited that the most likely causes of BER in susceptible cultivars are the interactions of (a) light and temperature on fruit enlargement, (b) inadequate xylem tissue development in the fruit, and (c) competition between leaves and fruit for the available Ca. Adams and Ho (1992) demonstrated that despite considerable differences in susceptibility to BER among the cultivars they studied, there were no differences in the amount of Ca accumulated by the fruit.

For moderately susceptible cultivars, a high incidence of mild, internal BER, may result from poor Ca transport within the fruit. However, a highly susceptible cultivar, with a high incidence of external BER may suffer from both poor Ca uptake by roots and poor xylem transport within the fruit (Ho *et al.*, 1993). In addition, Minamide and Ho (1993) implied that the regulation of Ca deposition in tomato fruit should be considered as a factor in cultivar susceptibility to BER.

Starck *et al.* (1994) indicated that for tomato cultivars that are tolerant to high temperature, increasing temperature will result in increasing translocation of ^{45}Ca to the fruit, while high temperature will have no effect on translocation in very temperature sensitive cultivars.

Genetic differences are also believed to contribute to cracking but the genetics of crack resistance is not well understood. Cultivars that are vegetatively vigorous may also be more resistant to cracking (Peet, 1992). In addition, Lukyanenko (1991) mentioned that various types of cracking including concentric, burst, and radial cracking are probably controlled by different genetic systems. Cultivars with high skin elasticity and low fruit sugar content possessed lower radial cracking (Nuechi and Handa, 1961 in: Lukyanenko, 1991). Peet (1992) suggested that the easiest way to decrease cracking was to use commercial cultivars selected for cracking resistance.

Chapter 3

Effect of calcium on yield and incidence of fruit disorders in three tomato cultivars

Introduction

Fruit disorders result in unmarketable tomatoes, reducing growers' income. Physiological disorders such as blossom-end rot (BER) and cracking have long been reported to be associated with calcium (Ca) deficiency, although this association is not always consistent (Shear, 1975). Poovaiah (1993) cited that research in the past two decades has clearly shown that increasing Ca^{2+} in various organs reduces the incidence and severity of various physiological disorders.

Other factors that influence the incidence of fruit disorders are environment and genetic susceptibility (Adams and Ho, 1992). The efficiency of Ca utilization in tomato is a heritable attribute and some cultivars were found to be more efficient than others (Kalloo, 1991). Adams and Ho (1992), reported that there were no differences in fruit Ca accumulation in cultivars that varied in susceptibility to BER.

The role of Ca in the development of fruit disorders remains controversial. Bar-Tal and Pressman (1996) found that the incidence of BER-affected fruit was related to the ratio of K/Ca in solution. However, Di Candilo and Silvestri (1994) reported that Ca did not affect BER. Nonami *et al.* (1995) also indicated that the incidence of BER was not directly caused by Ca deficiency in fruit. This inconsistency in results may be due to differences in calcium treatments, methods of application, or differences among cultivars.

The objective of this experiment was to investigate the effects of Ca nutrition on the yield and incidence of fruit disorders in three genetically diverse tomato cultivars.

Materials and Methods

Time and place of experiments

Three experiments were conducted in Fall 1995 (one experiment) and Spring 1996 (two experiments), which will be referred to as "Experiment 1", " Experiment 2", and "Experiment 3", respectively. The experiments were conducted in greenhouse #6, Department of Plant and Soil Science, The University of Tennessee, Knoxville.

Experimental Design

Experiment 1

The experiment was a factorial constructed in a randomized complete block design. Three cultivars (C), three calcium treatments (T) and two replications were set in each of three blocks. The treatment combinations were: T_1C_1, T_1C_2, T_1C_3, T_2C_1, T_2C_2, T_2C_3, T_3C_1, T_3C_2, T_3C_3 where T is the level of calcium concentration in solution (T_1 = 20 ppm Ca, T_2 = 220 ppm Ca, and T_3 = 1,020 ppm Ca; selected to represent very deficient, normal, and near toxic levels of calcium) and C denotes cultivars (C_1 = 'Mountain Supreme', C_2 = 'Celebrity', and C_3 = 'Sunrise'; selected to represent genetic differences in susceptibility to BER). The data were analyzed utilizing SAS (Release 6.11, SAS Institute Inc., Cary, NC. USA).

Experiment 2

The experiment was a factorial constructed in a randomized complete block design with two replications within each block and two sub-replications within each replication. Each of the three cultivars (C) received three levels of calcium treatments (T) and there were three blocks. The treatment combinations were: T_1C_1, T_1C_2, T_1C_3, T_2C_1, T_2C_2, T_2C_3, T_3C_1, T_3C_2, T_3C_3 where T is level of calcium concentration in solution (T_1 = 20 ppm Ca, T_2 = 220 ppm Ca, and T_3 = 1,020 ppm Ca; selected to represent very deficient, normal, and near toxic levels of calcium) and C denotes cultivars (C_1 = 'Mountain Supreme', C_2 = Celebrity, and C_3 = 'Sunrise'; selected to represent genetic differences in susceptibility to BER). In this experiment the plant population was twice as large as in the Fall 1995 experiment. The data were analyzed utilizing SAS (Release 6.11, SAS Institute Inc., Cary, NC. USA).

Experiment 3

The experimental design for experiment 3 was the same as experiment 1.

Irrigation and fertilization system

Irrigation was conducted by using 4 injector pumps (one Dosmatic Model 30-2S, Lewisville, Texas to provide all nutrients except Ca to all plants; three Dosatron Model DI 16-11GPM, Clearwater, Florida for calcium solutions) controlled by an Electronic Water

Timer (RainMatic 2000, RainMatic Corp., Omaha, NE 68108) to distribute the three separate calcium solutions. Nutrients were supplied four times (5 minutes/time) per day; at 06.00 a.m., 10.00 a.m., 02.00 p.m., and 06.00 p.m. Fertilizer and calcium were placed in separate buckets to avoid precipitation of fertilizer nutrients. The pH of solutions were maintained at 5.6 - 5.8. Calcium concentration in tap water was around 20 ppm, which was used as T_1. Two emitters were set in each pot providing approximately 1.6 liter of solution/5 minutes. Fertilization was varied during plant growth depending on the stage of plant growth. The basic nutrient source was 5-11-26 water soluble fertilizer (Peters Profesional, Hydrosol, Grace-Sierra Horticultural Products Co., 1001 Yosemite Drive, Milpitas, CA 95035) containing micronutrients. The ratio of N-P-K was adjusted to 1.0 : 0.6 : 2.5 by adding NH_4NO_3 (34% N) (Johnson City Chemical Co., Johnson City, TN 37601). Calcium was added as $CaCl_2 \cdot 2H_2O$ (Mallinckrodt Chemical, Inc., St. Louis, Missouri).

Experiment 1

The plants were given 30 ppm nitrogen then 60 ppm and 90 ppm of nitrogen for the first and second month and fruit growth stage, respectively. Other nutrients were applied in proportion to a 1.0 : 0.6 : 2.5 ratio of N-P-K and were derived from the 5-11-26 fertilizer.

Experiments 2 and 3

Nitrogen concentration was increased gradually and was maintained at 10 ppm (until 3 weeks old), 30 ppm (from 3 to 5 weeks old), 40 ppm (from 5 to 8 weeks old), 80 ppm (from 8 to 16 weeks old), 140 ppm (from 16 to 18 weeks old), and 180 ppm (from 18 to 24 weeks old). Other nutrients were applied in proportion to a 1.0 : 0.6 : 2.5 ratio of N-P-K and were derived from the 5-11-26 fertilizer.

Planting system

<u>Experiment 1</u>

Three week old seedlings were transplanted into 16-liter pots in September 1995, and grown as 1 plant/pot. The tomato plants were grown in modified Hoagland solutions utilizing a greenhouse hydroponic system with perlite (Carolina Perlite Co., Inc., Goldhill, NC 28071) as the root support media. The plants were spaced 30 cm apart within rows and 80 cm between rows. A hand vibrator was used three times a week to pollinate flowers.

<u>Experiment 2</u>

On January 10, 1996, tomato seeds were directly planted into 15-liter pots (4 seeds/pot) with perlite (Carolina Perlite Co., Inc., Goldhill, NC 28071) as the root support media. The plants were thinned to one plant/pot at the second leaf stage. The pots were spaced 30 cm apart within rows and 80 cm between rows. Plant growth was terminated above the 6th flower cluster. A hand vibrator was used three times a week to pollinate flowers.

<u>Experiment 3</u>

For this experiment three week old seedlings were transplanted from pots in experiment 2. The plant population was 1 plant/pot. The within row plant spacing was 30 cm. The distance between rows was 80 cm. Plant growth was terminated above the 6th flower cluster. A hand vibrator was used three times a week to pollinate flowers.

Pest control

Pests were controlled when necessary with Insecticidal Soap (Safer, Inc., 9959 Valley View Rd., Eden Prairie, MN 55344), Thiodan (Universal Cooperatives, Inc., Minneapolis, MN 55440), X·clude (Whitmire Research Laboratories, Inc., St. Louis, MO 63122), and Azatin EC (AgriDyne Technologies, Inc., 2401 So. Foothill Dr., Salt Lake City, UT 84109).

Data Collection

Fruit yield

The harvest period for experiment 1 was December 27, 1995 - March 8, 1996. For experiments 2 and 3 the harvest period was from May 23, 1996 - July 3, 1996. Harvesting was conducted two to three times a week.

Tomato fruits were harvested at the breaker stage (stage 2 in "Ripening Stages", California Tomato Board, 2017 N Gateway, Suite 102, Fresno, CA 93727). Total yield was expressed as fruit mass in grams. Marketable fruits were determined based on fruit size and the absence of physiological disorders. Fruits with diameters > 6.3 cm and free from disorders were categorized as marketable fruits. Fruit with a diameter < 6.3 cm were classified as unmarketable cull fruit. Average weight of marketable fruit was calculated by dividing total weight of marketable fruit by total number of marketable fruit.

Fruit disorders

Fruit disorders were evaluated by recording the incidences of blossom-end rot (BER), radial and concentric cracking, and catfacing (blossom-end scar). The evaluations for the disorders were not based on a certain scale or rating of incidence, but only on the presence or absence of the respective disorder.

Leaf calcium concentration

For all experiments, leaf samples were taken from the plants two weeks prior to final harvest. For experiment 1, calcium concentrations were measured for the leaves below the 1st, 3rd, and 5th flower cluster. In experiments 2 and 3, leaf samples were taken from above the 1st and 5th flower clusters. The leaves were dried in an oven at 70°C for 72 hours before grinding. An approximately 0.5 gram sample of ground leaf tissue was weighed using a Sartorius (A200S, GMBH, Gottingen, Germany) balance, put in a test tube, then ashed in a furnace (Thermolyne, Type 30400 Furnace) at 500°C for 12 hours. The ashed leaf samples were then diluted 80 : 1 with 2N HCl using a UniPump 300 (American Hospital Supply Corp, Miami, FL 33152, USA). Calcium concentration was measured with an ICP (inductively coupled plasma emission spectrophotometry). Leaf calcium content was expressed as $\mu g.g^{-1}$ dry weight.

Fruit calcium concentration

Fruit calcium concentration was determined from a one quarter radial section of each fruit. Fruit sections were freeze dried (Labconco LYPH-Lock 12, Labconco Corp, Kansas

City, MO 64132, USA) and one gram dry weight samples were analyzed by Inductively Coupled Plasma Emission Spectrophotometry (ICP) for calcium content. Calcium content was expressed as $\mu g.g^{-1}$ dry weight.

Solution samples

For experiments 1 and 3, nutrient solution samples including the solution going into the pots and the nutrient solution coming out of pots were taken once a week. For experiment 2, only the solution coming into the pots was sampled. Nutrient solution analysis by ICP, for the low (T_1) and medium (T_2) calcium treatments, was run without diluting, while the high (T_3) calcium treatment was diluted (1:20) for Ca and undiluted for all other nutrients.

Daily temperature and relative humidity (RH)

Temperature and relative humidity (RH) were observed daily around 11.00 a.m. by placing four thermohygrometers (Baxter, Control Co., 308 West Edgewood Friendwood, TX 77546) in the room for experiment 1. For experiments 2 and 3, only two thermohygrometers were placed in each experiment. For all experiments, thermohygrometers were placed at 150 cm above the floor and shielded from direct light exposure.

Results and Discussion

Leaf calcium concentration

Leaf calcium concentration was consistent from experiments 1, 2 and 3. The medium calcium treatment increased leaf calcium concentration across cultivars. The increases compared to the low calcium treatment were 110%, 156%, and 207% in experiments 1, 2 and 3, respectively. Leaf calcium content in the high calcium treatment was 3 - 4 times higher than leaf calcium content in the low calcium treatment. These results suggest that the high calcium treatment (1,020 ppm) was supraoptimal for tomato plants. Cultivars across calcium treatments were not different in leaf calcium content in any of the experiments (Appendix A, Tab. 1, 2 and 3, page 31-35; Appendix B, Fig. 1, 2 and 3, page 47-49).

A slight difference occurred between experiments conducted in the Fall and Spring for cultivar response in the low calcium treatment. In experiment 1, 'Mountain Supreme' had 20,934 $\mu g.g^{-1}$ dry weight leaf calcium which was 44% higher than the leaf calcium concentration of 'Celebrity'. This difference did not exist in experiments 2 and 3 (Appendix A, Tab. 1, 2 and 3, page 31-35). The difference in response may be due to the difference between the Fall and Spring seasonal growing condition, mainly temperature (Appendix F, Tab. 52 and 53, page 105) and light intensity.

Fruit calcium concentration

Fruit calcium concentration was increased by the medium calcium treatment across cultivars in experiments 1, 2 and 3. The medium calcium treatment increased fruit calcium concentration compared to the low calcium treatment by 812 $\mu g.g^{-1}$ dry weight (61%), 1,057 $\mu g.g^{-1}$ dry weight (153%), and 1056 $\mu g.g^{-1}$ dry weight (196%) in experiments 1, 2 and 3, respectively (Appendix A, Tab. 4, 5 and 6, page 36-40; Appendix B, Fig. 4, 5, and 6, page 50-52). Fruit analysis indicated that Ca uptake to the fruit may be restricted by high concentration of fruit K, as cited by English and Barker (1982), resulting in very low fruit Ca, especially in low Ca treatment.

Cultivar response was different between the Spring and Fall experiments for fruit calcium concentration. In experiment 1 (Fall), across treatments 'Mountain Supreme' had higher fruit calcium concentration which was 19% more than 'Celebrity'. This difference did not occur in experiments 2 and 3 (Spring) (Appendix A, Tab. 4, 5 and 6, page 36-40; Appendix B, Fig. 4, 5, and 6, page 50-52).

Relationship between leaf and fruit calcium

The relationship between leaf and fruit calcium in experiments 1 and 2 was slightly different. The relationship between leaf and fruit calcium concentrations in experiment 1 are shown in Fig. 7 (Appendix B, page 53). Leaf and fruit calcium concentration had a quadratic relationship for 'Mountain Supreme' and 'Sunrise' with peak points (97,674 $\mu g.g^{-1}$ dry weight; 2,342 $\mu g.g^{-1}$ dry weight) and (81,633 $\mu g.g^{-1}$ dry weight; 2,199 $\mu g.g^{-1}$ dry weight), respectively. This indicates that the high calcium treatment in the two cultivars tends to decrease fruit calcium concentration since the high calcium treatment resulted in 81,969 and 77,713 $\mu g g^{-1}$ dry weight leaf calcium, respectively for 'Mountain Supreme' and 'Sunrise' (Appendix A, Tab.1, page 31). However, the relationship was linear in 'Celebrity', indicating that the increase in leaf calcium concentration resulted in a corresponding increase in fruit calcium concentration.

In experiment 2 as shown in Fig. 8 (Appendix B, page 54), the fruit calcium concentration of cultivars 'Celebrity' and 'Sunrise' has a quadratic relationship with leaf calcium concentration, with peak points 64,684 $\mu g g^{-1}$ dry weight; 1,744 $\mu g g^{-1}$ dry weight and 78,534 $\mu g g^{-1}$ dry weight; 1,645 $\mu g g^{-1}$ dry weight, respectively. An increase of 10,000 $\mu g g^{-1}$ dry weight leaf calcium concentration for 'Mountain Supreme' resulted in an increase in fruit calcium concentration of 593 $\mu g g^{-1}$ dry weight. Fruit calcium concentration was not measured for fruit in experiment 3.

Total fruit weight per plant

For the three experiments conducted, the medium calcium treatments, give inconsistent results across cultivars. In experiment 1 (Fall), the medium calcium treatment did not differ from the low calcium treatment. Experiments 2 and 3 which were conducted in the Spring did not show a consistent effect of the medium calcium treatment on total fruit weight per plant. However, the high calcium treatment across cultivars decreased total fruit weight per plant by 1146 g (28%), 816 g (24%), and 691 g (23%) in experiments 1, 2, and 3, respectively, compared to the low calcium treatment (Appendix A, Tab. 1, 2 and 3, page 31-35).

There was a consistent cultivar effect for total fruit weight. In all three experiments 'Mountain Supreme' had lower total fruit weight than 'Celebrity', across calcium treatments. In experiments 2 and 3 'Sunrise' had the lowest total fruit weight among all three cultivars.

Average fruit weight

The effect of calcium on average fruit weight varied by season. There was no effect of calcium treatment on the average fruit weight in experiment 1 (Fall) (Appendix A, Tab. 7, page 41). However, the medium calcium treatment, across cultivars, significantly increased average fruit weight by 13 g (9%) and 29 g (22%) in experiments 2 and 3 (Spring), respectively. In the Spring the high calcium treatment reduced average fruit weight by 19 g (12%) and 32 g (24%) in experiments 2 and 3, respectively, relative to the low calcium treatment (Appendix A, Tab. 8 and 9, page 42-43).

The low calcium treatment in all experiments still resulted in high values for average fruit weight (Appendix A, Tab. 7, 8 and 9, page 41-43). This supported the fact that the low Ca treatment resulted in low calcium concentration of fruit. It can be caused by the dilution of fruit Ca in accordance with the enlargement of the fruit (Shear, 1975). While there was no addition of Ca solution which was needed.

Incidence of BER

The incidence of BER was highest in clusters 5 and 6 (data not shown). This is possibly due to the low calcium concentration in the upper part of the plants (above the 5th flower cluster). Leaf calcium content was lower in the upper leaves (Appendix A, Tab. 2 and 3, page 32-34).

The increase in fruit calcium concentration due to the medium and high calcium treatments appeared to suppress the incidence of BER. The plants in the low calcium treatment had a higher percentage of fruit with BER than plants in the medium or high calcium treatment. These results were similar to those reported by Sonneveld and Voogt (1991). It is understandable because fruits from plants grown in the low calcium treatment had low calcium content. Calcium can not be redistributed from older to newer tissue (Millaway and Wiersholm, 1979).

Calcium treatments across cultivars in all three experiments had similar affects on incidence of BER. The medium calcium treatment reduced the incidence of BER in experiments 1, 2, and 3, respectively, relative to the low calcium treatment. Across calcium treatments, 'Mountain Supreme' had less incidence of BER than 'Celebrity' in experiments 1, 2, and 3, respectively (Appendix A, Tab. 10, 11 and 12, page 44-45; Appendix B, Fig. 9, 10 and 11, page 55-57). However, 'Mountain Supreme' and 'Celebrity' were not significantly different in leaf and fruit Ca concentrations. Ho *et al.* (1995) reported that the incidence of BER was not always related to efficiency in Ca uptake among cultivars.

Incidence of cracking

The incidence of fruit cracking was not affected by the medium calcium treatment in the Fall 1995 experiment. In both Spring 1996 experiments, the medium and high calcium treatments significantly increased the incidence of fruit cracking (Appendix A, Tab. 10, 11, and 12, page 44-45). These results are different from those reported by Peet (1992) who suggested that calcium treatment reduced tomato fruit cracking. The increase of incidence of cracking may be due to the increase in tomato fruit size in the Spring 1996 experiments compared to Fall 1995 (Appendix A, Tab. 7, 8 and 9, page 41-43). Another possibility was that the rigidity of the fruit cell walls was increased by the medium calcium treatment, resulting in an increase in the incidence of cracking when turgor pressure was high. 'Mountain Supreme' consistently had a lower incidence of fruit cracking than 'Celebrity'.

Incidence of catface

A very small percentages of fruits in each experiment were catfaced (Appendix A, Tab. 10, 11, and 12, page 44-45). There was no significant difference between the low and medium calcium treatment in any of the experiments. These results suggests that calcium is not an important factor in incidence of catfacing. Wien and Turner (1994) reported that catfacing was mostly influenced by plant age and air temperature. Cultivar differences did not occur in the Fall 1995 experiment. However, in the Spring 1996 experiments, across calcium treatments, 'Mountain Supreme' had a lower incidence of catfacing than 'Celebrity' (Appendix A, Tab. 10, 11 and 12, page 44-45).

Total weight of marketable fruit per plant

In experiments 1, 2, and 3, calcium treatments across cultivars, had different effects on total weight of marketable fruit per plant. In experiment 1, the medium calcium treatment did not affect total weight of marketable fruit. However, in experiments 2 and 3, the medium calcium treatment, across cultivars, increased the total weight of marketable fruit per plant by 480 g (18%) and 685 g (36%), respectively. The high calcium treatment reduced the total weight of marketable fruit per plant by 546 g (18%), 555 g (21%), and 823 g (44%) in experiment 1, 2 and 3, respectively, compared to the low calcium treatment (Appendix A, Tab. 7, 8 and 9, page 41-43; Appendix B, Fig. 12, 13, and 14, page 58-60). Cultivars 'Mountain Supreme' and 'Celebrity', across calcium treatments, did not differ from each other in total weight of marketable fruit per plant. 'Sunrise', across calcium treatments, had the the lowest total weight of marketable fruit per plant.

Average weight of marketable fruit

There was no difference between the low and medium calcium treatments, across cultivars, in average marketable fruit weight. However, compared to the low calcium treatment, the high calcium treatment decreased the average marketable fruit weight by 21 g (13%), 24 g (13%), and 36 g (18%) in experiment 1, 2, and 3, respectively (Appendix A, Tab. 7, 8 and 9, page 41-43). The high calcium treatment (1,020 ppm) may be too high (near toxic) for tomato plants. In all experiments, across calcium treatments, 'Mountain Supreme' had the lowest average marketable fruit weight. Cultivars 'Celebrity' and 'Sunrise' did not differ from each other in average weight of marketable fruit.

Chapter 4

Conclusion

From the experiments conducted, I conclude that:

1. Across cultivars, the medium calcium treatment (220 ppm) consistently increased leaf and fruit calcium concentrations when compared to the low calcium treatment (20 ppm). Consequently, the medium calcium treatment appeared to reduce the incidence of blossom-end rot (BER) as BER incidence was also consistently lower in the medium calcium treatment.

2. The medium calcium treatment, across cultivars, did not consistently affect the total weight of marketable fruit per plant. This may be due to differences in seasons (temperature and relative humidity) among the experiments. The medium calcium treatment did not significantly affect the total weight of marketable fruit per plant in experiment 1 (Fall 1995) but significantly increased the total weight of marketable fruit in experiments 2 and 3 (Spring 1996) compared to the low calcium treatment. It was probably due to the different growing condition, day lengths, light intensity, and day and night temperature between Fall and Spring experiments. In Spring experiments plant growth was terminated above 6^{th} flower cluster. Therefore, average fruit weight in Spring was larger than Fall experiment.

3. The high calcium treatment (1020 ppm), across cultivars, consistently reduced total fruit weight per plant, average fruit weight, total weight of marketable fruit, and average marketable fruit weight in all experiments conducted. The high calcium treatment was

apparently too high (near toxic as leaf burn symptoms were observed) for tomato plants. The 220 ppm calcium concentration in these experiments was mostly nearly optimum.

4. Across calcium treatments, cultivar 'Celebrity', was consistently more susceptible than 'Mountain Supreme' to incidence of BER, cracking and catface.

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Appendices

Appendix A

Tables

Table 1. The average values of tomato leaf nutrients in Fall 1995 (Experiment 1)

Treatment Combinations		Variables[z]					
		Leaf Ca	SD	Leaf B	SD	Leaf K	SD
Calcium treatments	Cultivars	...µg.g⁻¹ dry weight...					
Low	Mountain Supreme	47178.97	5108.35	193.25	53.91	28187.71	6339.94
Low	Celebrity	26245.14	3838.37	153.92	54.17	28445.54	6419.09
Low	Sunrise	36331.78	2645.99	181.00	37.76	33001.68	6334.90
Medium	Mountain Supreme	76095.30	9231.88	146.34	36.30	26669.57	6959.75
Medium	Celebrity	73923.07	8666.80	137.79	30.93	29730.74	7823.27
Medium	Sunrise	80431.74	18273.91	151.18	29.31	29764.39	7918.98
High	Mountain Supreme	81969.45	15766.96	143.73	38.06	31816.42	7974.86
High	Celebrity	77669.39	16900.36	110.77	33.23	32669.70	8494.54
High	Sunrise	77712.84	11680.87	132.42	36.70	36996.30	8177.71

Table 1. (Continued)

Treatment Combinations		Variables[z]					
		Leaf Mg	SD	Leaf P	SD	Leaf S	SD
Calcium treatments	Cultivars	...µg.g⁻¹ dry weight...					
Low	Mountain Supreme	21328.18	6239.22	14794.72	4877.33	19055.45	5273.49
Low	Celebrity	15864.73	6412.94	8193.50	3046.80	13135.84	3681.59
Low	Sunrise	18701.95	5238.17	9255.47	3564.20	16460.35	2823.64
Medium	Mountain Supreme	6744.22	2523.92	8417.67	3259.85	20232.21	5815.45
Medium	Celebrity	5303.56	2130.74	6520.30	2520.48	13273.46	3108.56
Medium	Sunrise	6545.14	1737.60	8220.19	3410.91	15968.84	5010.44
High	Mountain Supreme	2778.54	1028.25	5487.83	1994.10	16123.49	4666.50
High	Celebrity	2570.57	991.07	4607.19	1666.17	11313.07	2803.52
High	Sunrise	2863.90	1317.93	5576.00	2138.71	13835.54	3187.57

[z] Leaf Ca= leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 2. The average values of tomato leaf nutrients in Spring 1996 (Experiment 2)

Treatment Combinations		Variables[z]					
		1stleafCa	SD	5thleafCa	SD	LeafCa	SD
Calcium treatments	Cultivars	.... µg.g^{-1} dry weight					
Low	Mt. Supreme	30042.56	6390.15	20011.86	3342.64	25595.70	7596.15
Low	Celebrity	26313.97	3422.82	20504.73	3509.29	24317.00	5054.59
Low	Sunrise	31386.20	5918.35	21115.30	2998.38	26341.69	7116.38
Medium	Mt. Supreme	72343.41	7397.68	56103.92	6224.90	65329.67	10722.26
Medium	Celebrity	69170.87	8529.45	59998.43	10550.47	64603.21	10357.56
Medium	Sunrise	67436.68	9633.21	61861.68	10735.66	65466.53	10177.65
High	Mt. Supreme	80312.44	14819.17	73935.75	8688.67	77624.68	12769.18
High	Celebrity	85476.67	11487.82	81840.38	9901.73	84112.12	10818.39
High	Sunrise	82914.74	9801.07	79256.14	6783.71	81056.55	8459.34

Table 2. (Continued)

Treatment Combinations		Variables[z]					
		Leaf B	SD	Leaf K	SD	Leaf Mg	SD
Calcium treatments	Cultivars	.... µg.g^{-1} dry weight					
Low	Mt. Supreme	253.95	55.33	46104.12	9426.60	20058.47	4510.44
Low	Celebrity	241.91	39.62	44203.54	7658.51	17871.14	2759.79
Low	Sunrise	249.30	68.86	43920.68	8489.31	19290.28	4635.48
Medium	Mt. Supreme	209.32	46.87	36205.50	9414.88	7287.47	1664.52
Medium	Celebrity	209.15	39.60	31895.12	6434.07	5898.56	1532.74
Medium	Sunrise	214.24	47.05	39684.92	6556.93	6661.10	1211.28
High	Mt. Supreme	181.01	58.23	35699.72	9146.98	4012.75	841.48
High	Celebrity	161.83	39.25	30750.10	6859.71	3585.61	774.66
High	Sunrise	168.61	45.68	32690.64	8199.05	3915.96	845.06

[z] 1stleafCa=calcium concentration in the leaf above the first flower cluster; 5thleafCa=calcium concentration in the leaf above the fifth flower cluster; LeafCa=the average leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 2. (Continued)

Treatment Combinations		Variables[z]			
		Leaf P	SD	Leaf S	SD
Calcium treatments	Cultivars	.... µg.g^{-1} dry weight			
Low	Mt. Supreme	10919.08	2457.77	17089.81	3083.92
Low	Celebrity	9231.29	2310.79	13469.94	3103.58
Low	Sunrise	10742.79	3416.69	15675.57	3011.65
Medium	Mt. Supreme	8761.69	1568.25	15976.49	2799.88
Medium	Celebrity	7459.44	1926.60	11896.99	2931.62
Medium	Sunrise	10013.60	1980.92	14585.93	2807.54
High	Mt. Supreme	7849.85	1682.68	13585.98	3165.19
High	Celebrity	6150.49	1871.98	10521.54	2847.59
High	Sunrise	7826.93	1811.90	12086.20	2571.06

[z] 1stleafCa=calcium concentration in the leaf above the first flower cluster; 5thleafCa=calcium concentration in the leaf above the fifth flower cluster; LeafCa=the average leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 3. The average values of tomato leaf nutrients in Spring 1996 (Experiment 3)

Treatment Combinations		Variables[z]					
		1stleaf Ca	SD	5thleaf Ca	SD	Leaf Ca	SD
Calcium treatments	Cultivars	$\mu g.g^{-1}$ dry weight					
Low	Mt. Supreme	31445.97	7973.55	19574.39	1766.84	26339.51	4609.54
Low	Celebrity	26690.37	6041.36	20450.69	2816.29	23570.53	3552.47
Low	Sunrise	29178.34	4331.29	19615.32	1126.13	23799.03	2897.78
Medium	Mt. Supreme	80979.00	15325.63	61344.95	9206.41	71207.99	11684.40
Medium	Celebrity	89170.05	21584.36	67930.52	7747.75	78550.28	14398.48
Medium	Sunrise	81694.11	17254.53	56580.32	2814.29	76220.75	4800.14
High	Mt. Supreme	102273.82	16226.14	83868.31	2709.75	94527.99	7520.72
High	Celebrity	115029.41	8094.90	81671.67	6249.58	100387.68	5481.67
High	Sunrise	97952.23	18664.97	82443.05	14810.74	90197.64	13567.38

Table 3. (Continued)

Treatment Combinations		Variables[z]					
		Leaf B	SD	Leaf K	SD	Leaf Mg	SD
Calcium treatments	Cultivars	$\mu g.g^{-1}$ dry weight					
Low	Mt. Supreme	376.36	48.75	39563.29	4292.48	25506.46	6772.31
Low	Celebrity	350.94	50.77	42229.53	3509.88	22196.91	4549.53
Low	Sunrise	377.66	49.71	42087.50	6431.00	22371.56	4623.92
Medium	Mt. Supreme	303.17	38.40	23834.57	5744.10	9062.61	1838.27
Medium	Celebrity	284.02	34.02	23138.15	3270.06	8809.17	2574.91
Medium	Sunrise	302.85	41.66	29608.84	2627.60	9066.73	2511.38
High	Mt. Supreme	251.26	38.18	24925.06	3542.87	5032.10	736.23
High	Celebrity	266.84	22.29	24401.49	6343.48	4844.82	974.70
High	Sunrise	252.97	27.77	26435.31	5183.98	4370.06	960.56

[z] 1st leaf Ca= the average leaf calcium concentration above 1st flower cluster; 5thleaf Ca=the average leaf calcium concentration above 5th flower cluster; Leaf Ca=the average leaf calcium concentration; Leaf B=the average leaf boron concentration; Leaf K=the average leaf potassium concentration; Leaf Mg=the average leaf magnesium concentration; Leaf P=the average leaf phosphorous concentration; Leaf S=the average leaf sulfur concentration.

Table 3. (Continued)

Treatment Combinations		Variables[z]			
		Leaf P	SD	Leaf S	SD
Calcium treatments	Cultivars	.... µg.g^{-1} dry weight			
Low	Mt. Supreme	8749.97	1639.02	14218.91	3138.76
Low	Celebrity	7186.24	1465.52	10438.61	3300.86
Low	Sunrise	9056.53	3058.51	13628.89	2603.43
Medium	Mt. Supreme	7133.56	1349.11	11511.66	2474.85
Medium	Celebrity	6319.28	830.95	11141.82	2221.85
Medium	Sunrise	7161.13	1173.86	12521.10	2824.82
High	Mt. Supreme	5412.81	533.68	7983.54	1127.39
High	Celebrity	5035.74	952.03	7426.07	1382.72
High	Sunrise	5003.07	896.09	7325.90	1732.84

[z] 1st leaf Ca= the average leaf calcium concentration above 1st flower cluster; 5thleaf Ca=the average leaf calcium concentration above 5th flower cluster; Leaf Ca=the average leaf calcium concentration; Leaf B=the average leaf boron concentration; Leaf K=the average leaf potassium concentration; Leaf Mg=the average leaf magnesium concentration; Leaf P=the average leaf phosphorous concentration; Leaf S=the average leaf sulfur concentration.

Table 4. The average values of tomato fruit nutrients in Fall 1995 (Experiment 1)

Treatment Combinations		Variables[z]					
		Fruit Ca	SD	Fruit B	SD	Fruit K	SD
Calcium treatments	Cultivars	....µg.g^{-1} dry weight					
Low	Mt. Supreme	1585.04	621.29	90.99	26.70	45673.98	13672.99
Low	Celebrity	1319.79	489.07	80.62	37.06	35767.65	13354.25
Low	Sunrise	1080.15	414.79	78.03	26.11	43082.14	16526.78
Medium	Mt. Supreme	2207.82	1045.70	97.88	50.57	39757.26	11368.17
Medium	Celebrity	1817.40	1048.98	81.92	37.64	36938.06	13202.10
Medium	Sunrise	2396.66	951.61	105.15	38.79	49931.22	18187.63
High	Mt. Supreme	2298.86	1023.34	94.08	36.61	44106.28	15440.95
High	Celebrity	1767.13	687.88	84.05	31.75	43740.31	13349.76
High	Sunrise	1811.34	728.74	97.17	30.84	55213.57	14238.68

Table 4. (Continued)

Treatment Combinations		Variables[z]					
		Fruit Mg	SD	Fruit P	SD	Fruit S	SD
Calcium treatments	Cultivars	....µg.g^{-1} dry weight					
Low	Mt. Supreme	2320.543	757.08	7812.42	2452.20	2037.51	626.06
Low	Celebrity	1991.137	749.85	4969.99	2062.07	1514.27	520.78
Low	Sunrise	2547.629	1136.13	7413.07	3200.47	1962.33	848.12
Medium	Mt. Supreme	1499.047	439.46	6081.95	2146.07	1727.86	705.73
Medium	Celebrity	1531.555	631.31	4382.21	1808.85	1132.66	499.72
Medium	Sunrise	2034.583	757.25	7260.37	3097.32	1817.69	748.49
High	Mt. Supreme	1541.406	650.56	5632.06	2184.56	1406.05	505.52
High	Celebrity	1436.708	469.65	4434.51	1454.92	1012.98	401.54
High	Sunrise	2020.383	693.19	6777.31	2290.43	1463.04	389.87

[z] Fruit Ca= fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 5. The average values of tomato fruit nutrients in Spring 1996 (Experiment 2)

Treatment Combinations		Variables[z]					
		1stfruitCa	SD	Fruit Ca	SD	Fruit B	SD
Calcium treatments	Cultivars	.... $\mu g.g^{-1}$ dry weight					
Low	Mt. Supreme	776.80	119.38	724.42	135.07	114.23	33.85
Low	Celebrity	784.59	89.73	743.19	150.20	117.36	31.20
Low	Sunrise	617.98	126.85	605.64	104.94	118.68	34.64
Medium	Mt. Supreme	1823.27	453.21	1894.69	348.80	125.43	27.74
Medium	Celebrity	1727.64	280.27	1764.81	255.04	124.71	29.89
Medium	Sunrise	1601.07	225.61	1585.31	354.13	124.83	31.97
High	Mt. Supreme	2034.61	350.46	1960.66	343.55	102.85	39.58
High	Celebrity	2343.90	174.80	2066.78	311.92	105.12	54.89
High	Sunrise	1709.80	295.15	1722.44	398.35	117.43	30.46

Table 5. (Continued)

Treatment Combinations		Variables[z]			
		Fruit K	SD	Fruit Mg	SD
Calcium treatments	Cultivars	.... $\mu g.g^{-1}$ dry weight			
Low	Mt. Supreme	34864.80	2382.45	1638.38	175.51
Low	Celebrity	39692.36	4605.75	1922.66	267.70
Low	Sunrise	40041.77	5139.73	1953.32	361.65
Medium	Mt. Supreme	38071.02	3444.55	1210.23	159.67
Medium	Celebrity	40037.29	6678.63	1131.25	242.67
Medium	Sunrise	41885.53	4464.56	1299.99	261.03
High	Mt. Supreme	40123.03	5173.27	1017.05	130.42
High	Celebrity	39489.60	5910.07	931.61	163.31
High	Sunrise	38400.76	5327.87	944.05	90.67

[z] 1stfruitCa=calcium concentration in first cluster fruit; Fruit Ca=the average fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 5. (Continued)

Treatment Combinations		Variables[z]			
		Fruit P	SD	Fruit S	SD
Calcium treatments	Cultivars	.... $\mu g.g^{-1}$ dry weight			
Low	Mt. Supreme	4716.65	551.09	1419.40	155.66
Low	Celebrity	4610.46	783.56	1408.20	251.71
Low	Sunrise	4938.66	820.05	1523.97	187.85
Medium	Mt. Supreme	4512.98	585.09	1424.83	256.27
Medium	Celebrity	3749.57	737.59	941.86	290.83
Medium	Sunrise	4542.31	707.73	1219.97	307.12
High	Mt. Supreme	4326.54	470.86	1291.15	129.07
High	Celebrity	3662.23	327.86	815.89	209.23
High	Sunrise	3889.31	399.55	890.46	136.61

[z] 1stfruitCa=calcium concentration in first cluster fruit; Fruit Ca=the average fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 6. The average values of tomato fruit nutrients in Spring 1996 (Experiment 3)

Treatment Combinations		Variables[z]					
		1stFruCa	SD	3rdFruCa	SD	Fruit Ca	SD
Calcium treatments	Cultivars	.... μg.g[-1] dry weight					
Low	Mt. Supreme	659.29	184.95	535.59	61.35	601.03	150.01
Low	Celebrity	589.55	157.59	452.78	61.53	537.52	123.20
Low	Sunrise	437.72	55.73	501.27	150.51	487.72	129.90
Medium	Mt. Supreme	1823.56	265.06	1811.96	480.21	1720.61	402.47
Medium	Celebrity	1890.88	483.45	1616.34	232.14	1807.45	418.49
Medium	Sunrise	1345.60	484.81	927.33	940.95	1299.19	469.88
High	Mt. Supreme	1778.67	209.74	2374.70	597.14	2079.46	471.98
High	Celebrity	1884.49	.	2871.15	.	2204.14	534.16
High	Sunrise	1057.21	451.12	.	.	1057.21	451.12

Table 6. (Continued)

Treatment Combinations		Variables[z]					
		Fruit B	SD	Fruit K	SD	Fruit Mg	SD
Calcium treatments	Cultivars	.... μg.g[-1] dry weight					
Low	Mt. Supreme	109.55	44.63	31673.75	2420.18	1684.10	280.16
Low	Celebrity	99.08	16.65	33661.13	4311.37	1748.27	298.83
Low	Sunrise	93.66	28.51	31198.32	3876.30	1585.99	366.10
Medium	Mt. Supreme	106.89	20.48	30000.62	3390.95	969.42	164.83
Medium	Celebrity	107.25	17.83	33585.66	6404.13	1035.46	212.75
Medium	Sunrise	111.90	28.38	34627.32	5365.06	1170.79	284.56
High	Mt. Supreme	100.72	23.74	29062.86	4128.84	757.49	137.30
High	Celebrity	90.36	18.90	30303.41	9451.75	628.86	185.45
High	Sunrise	83.99	9.29	35849.79	8645.26	1041.58	557.73

[z] 1stFruCa=calcium concentration in first cluster fruit; 3rdFruCa=calcium concentration in third cluster fruit; Fruitca=the average fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 6. (Continued)

Treatment Combinations		Variables[z]			
		Fruit P	SD	Fruit S	SD
Calcium treatments	Cultivars	.... μg.g^{-1} dry weight			
Low	Mt. Supreme	4370.21	781.13	1156.09	181.96
Low	Celebrity	3709.28	631.69	865.73	186.43
Low	Sunrise	3871.54	821.19	920.49	204.96
Medium	Mt. Supreme	3391.89	536.23	706.53	166.84
Medium	Celebrity	3029.23	578.40	535.42	115.92
Medium	Sunrise	3810.05	666.79	829.59	233.37
High	Mt. Supreme	3078.63	496.34	611.92	92.82
High	Celebrity	2532.78	652.55	387.30	121.25
High	Sunrise	3780.26	1279.55	647.73	216.33

[z] 1stFruCa=calcium concentration in first cluster fruit; 3rdFruCa=calcium concentration in third cluster fruit; Fruitca=the average fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 7. The average values of tomato yield components in Fall 1995 (Experiment 1)

Treatment Combinations		Variables[z]					
Calcium treatments	Cultivars	Totfruwe	SD	Totfru#	SD	Avgfruwe	SD
		.... g					
Low	Mt. Supreme	4027.15	1654.90	40.07	15.97	100.58	8.80
Low	Celebrity	4840.56	1023.44	39.82	7.75	121.02	17.20
Low	Sunrise	3378.72	1240.68	29.00	9.63	134.77	10.65
Medium	Mt. Supreme	4051.57	1113.38	42.79	8.64	94.83	9.09
Medium	Celebrity	4259.35	1160.63	32.31	13.10	144.19	41.26
Medium	Sunrise	3785.23	1031.20	28.65	8.12	135.76	28.21
High	Mt. Supreme	2982.21	540.71	30.33	3.35	89.58	5.34
High	Celebrity	3067.13	354.27	26.00	4.98	120.04	14.93
High	Sunrise	2758.06	609.34	22.93	3.03	117.27	19.63

Table 7. (Continued)

Treatment Combinations		Variables[z]					
Calcium treatments	Cultivars	Mkfruwe	SD	Mkfru#	SD	Avmkfruwe	SD
		.... g				.... g	
Low	Mt. Supreme	3212.67	888.33	21.90	7.41	147.75	16.18
Low	Celebrity	3486.46	581.52	16.90	4.99	181.36	37.12
Low	Sunrise	2459.46	800.23	14.33	4.23	171.25	20.84
Medium	Mt. Supreme	3218.68	501.91	22.21	4.04	147.80	10.82
Medium	Celebrity	3375.26	360.65	18.52	2.17	181.79	6.60
Medium	Sunrise	3219.84	293.19	17.81	1.26	182.54	9.76
High	Mt. Supreme	2604.56	488.16	19.50	3.39	134.63	22.00
High	Celebrity	2592.51	505.83	17.33	3.67	150.57	18.38
High	Sunrise	2324.79	611.85	15.24	4.04	152.48	8.66

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe = marketable fruit weight; Avmkfruwe=the average marketable fruit weight.

Table 8. The average values of tomato yield components in Spring 1996 (Experiment 2)

Treatment Combinations		Variables[z]					
		Totfruwe	SD	Totfru#	SD	Avgfruwe	SD
Calcium treatments	Cultivars	.... g				.... g	
Low	Mt. Supreme	3483.87	819.22	27.25	5.56	124.21	12.93
Low	Celebrity	3634.15	1034.16	25.00	6.76	147.87	28.39
Low	Sunrise	3011.38	669.55	17.00	3.28	178.29	29.13
Medium	Mt. Supreme	3591.33	690.33	26.33	4.14	133.56	19.68
Medium	Celebrity	4409.07	698.85	23.58	4.89	185.92	30.63
Medium	Sunrise	3160.21	905.63	19.08	5.65	169.55	32.27
High	Mt. Supreme	2568.86	417.98	20.58	2.91	124.94	10.95
High	Celebrity	2714.27	763.47	19.91	4.14	138.87	15.30
High	Sunrise	2397.69	595.69	16.62	3.80	130.61	17.80

Table 8. (Continued)

Treatment Combinations		Variables[z]					
		Mkfruwe	SD	Mkfru#	SD	Avmkfruwe	SD
Calcium treatments	Cultivars	.... g				.... g	
Low	Mt. Supreme	2758.90	694.74	18.50	2.71	147.80	21.53
Low	Celebrity	2534.43	863.55	13.40	5.47	187.04	24.35
Low	Sunrise	2502.18	565.27	12.33	2.57	204.85	35.35
Medium	Mt. Supreme	3236.97	672.89	20.33	3.87	156.17	14.88
Medium	Celebrity	3431.01	510.32	15.68	3.72	214.90	38.42
Medium	Sunrise	2568.50	813.32	12.67	3.87	203.49	24.66
High	Mt. Supreme	2268.24	354.25	16.58	2.54	140.52	14.22
High	Celebrity	1866.24	337.80	11.08	2.97	164.83	22.92
High	Sunrise	1996.60	453.03	11.35	3.23	163.78	24.46

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe = marketable fruit weight; Mkfru#=marketable fruit number, Avmkfruwe=the average marketable fruit weight.

Table 9. The average values of yield components in Spring 1996 (Experiment 3)

Treatment Combinations		Variables[z]					
		Totfruwe	SD	Totfru #	SD	Avgfruwe	SD
Calcium treatments	Cultivars	.... g				.... g	
Low	Mt. Supreme	3114.60	432.22	24.17	3.31	129.14	9.07
Low	Celebrity	3349.10	588.33	25.00	3.22	135.23	24.36
Low	Sunrise	2447.85	1028.13	19.00	4.93	136.22	23.04
Medium	Mt. Supreme	3558.69	488.07	26.17	5.34	130.32	16.96
Medium	Celebrity	4841.57	583.84	25.83	4.62	190.63	29.39
Medium	Sunrise	2851.73	994.57	17.33	6.12	168.11	45.41
High	Mt. Supreme	2342.02	701.88	21.00	6.72	113.20	17.43
High	Celebrity	2629.77	816.92	22.08	7.60	98.96	10.83
High	Sunrise	1867.90	460.82	20.33	4.93	92.16	9.39

Table 9. (Continued)

Treatment Combinations		Variables[z]					
		Mkfruwe	SD	Mkfru #	SD	Avmkfr uwe	SD
Calcium treatments	Cultivars	.... g				.... g	
Low	Mt. Supreme	2098.51	264.97	13.50	2.43	156.74	10.64
Low	Celebrity	1969.25	357.45	9.33	1.86	212.22	12.59
Low	Sunrise	1560.09	634.58	6.33	3.20	230.36	13.95
Medium	Mt. Supreme	2718.38	527.87	17.17	3.60	159.64	18.49
Medium	Celebrity	2882.86	738.80	13.33	3.67	216.96	13.40
Medium	Sunrise	2080.40	692.58	11.05	4.12	196.03	30.50
High	Mt. Supreme	1540.20	483.40	10.49	2.17	133.37	13.67
High	Celebrity	1074.41	595.20	5.10	3.30	203.76	5.89
High	Sunrise	544.98	435.02	3.67	3.08	155.64	14.38

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe = marketable fruit weight; Mkfru#=marketable fruit number; Avmkfruwe=the average marketable fruit weight.

Table 10. The average values of tomato fruit disorders in Fall 1995 (Experiment 1)

Treatment Combinations		Variables^z					
Calcium treatments	Cultivars	BER	SD	Cracking	SD	Catfac e	SD
		.... %					
Low	Mt. Supreme	2.10	2.50	0.00	0.00	0.25	0.00
Low	Celebrity	16.60	14.53	3.37	3.22	3.47	3.49
Low	Sunrise	14.07	9.23	3.28	2.79	1.90	2.34
Medium	Mt. Supreme	0.00	0.00	0.00	0.00	1.98	2.24
Medium	Celebrity	2.03	2.29	3.68	2.39	0.62	1.51
Medium	Sunrise	0.63	1.55	0.98	2.41	1.02	2.37
High	Mt Supreme	0.00	0.00	0.00	0.00	1.00	1.61
High	Celebrity	5.38	5.45	0.14	0.00	2.02	2.32
High	Sunrise	1.18	2.89	0.00	0.00	1.05	2.01

^{z} BER = incidence of blossom-end rot; Cracking = incidence of cracking;
Catface = incidence of catface.

Table 11. The average values of tomato fruit disorders in Spring 1996 (Experiment 2)

Treatment Combinations		Variables^z					
		BER	SD	Cracking	SD	Catface	SD
Calcium treatments	Cultivars	.... %					
Low	Mt. Supreme	20.83	2.50	0.00	0.00	0.96	1.89
Low	Celebrity	32.33	14.53	0.03	0.00	1.63	1.94
Low	Sunrise	17.17	9.23	0.02	0.00	0.62	1.51
Medium	Mt. Supreme	4.75	0.00	0.07	0.00	0.81	1.40
Medium	Celebrity	9.67	2.29	6.89	5.66	5.19	4.91
Medium	Sunrise	9.08	1.55	2.31	3.64	0.17	0.00
High	Mt. Supreme	3.00	0.00	0.00	0.00	1.46	2.56
High	Celebrity	16.50	5.45	1.83	2.59	3.92	4.68
High	Sunrise	5.08	2.90	2.63	3.76	1.83	3.39

^{z} BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.

Table 12. The average values of tomato fruit disorders in Spring 1996 (Experiment 3)

Treatment Combinations		Variables[z]					
		BER	SD	Cracking	SD	Catface	SD
Calcium treatments	Cultivars	.... %					
Low	Mt. Supreme	35.60	11.70	2.47	15.55	0.78	9.05
Low	Celebrity	53.29	16.09	2.26	14.12	6.41	24.42
Low	Sunrise	47.69	17.92	0.45	0.00	3.55	18.25
Medium	Mt. Supreme	13.67	8.13	4.10	19.44	2.39	14.85
Medium	Celebrity	23.86	10.30	9.14	28.04	1.60	12.26
Medium	Sunrise	10.62	10.45	3.73	18.05	3.37	18.05
High	Mt. Supreme	11.21	13.18	3.65	19.79	0.06	0.00
High	Celebrity	53.48	18.16	9.99	29.30	1.84	14.21
High	Sunrise	41.20	24.64	1.19	10.60	0.10	0.00

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.

Appendix B

Figures

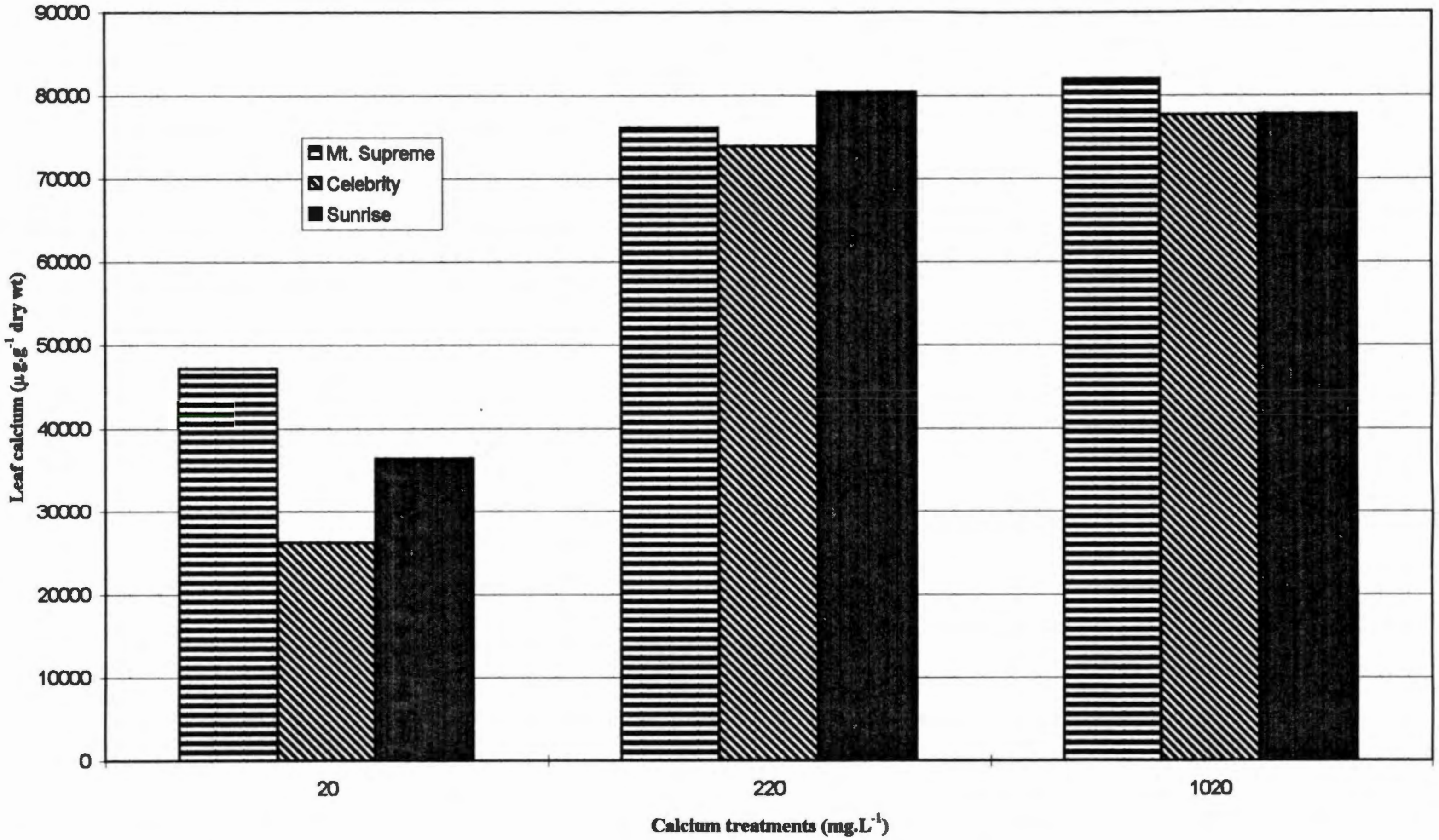

Figure 1. Effect of calcium treatments on leaf calcium concentration in Fall 1995 (Experiment 1).

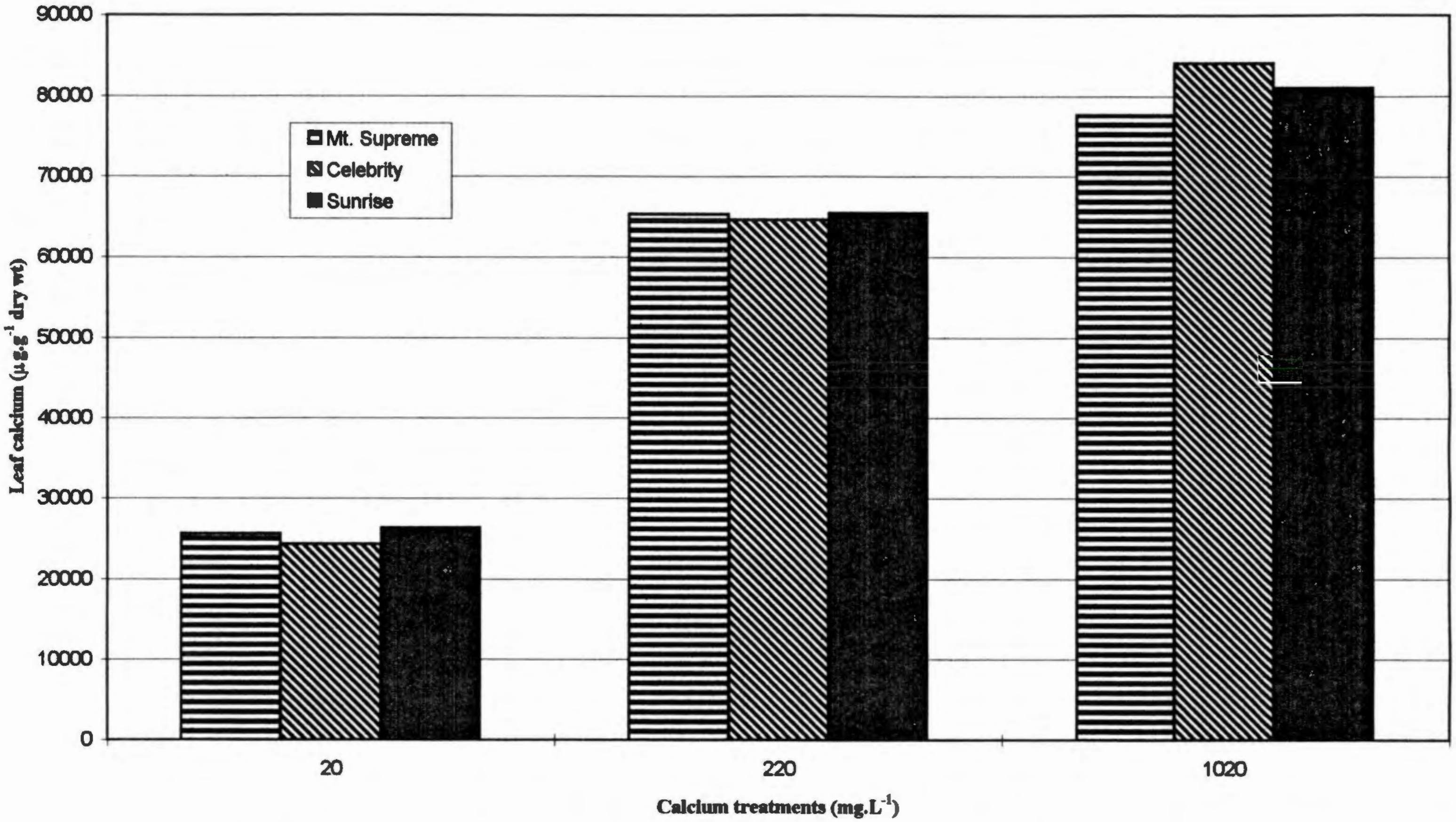

Figure 2. Effect of calcium treatments on tomato leaf calcium concentration in Spring 1996 (Experiment 2).

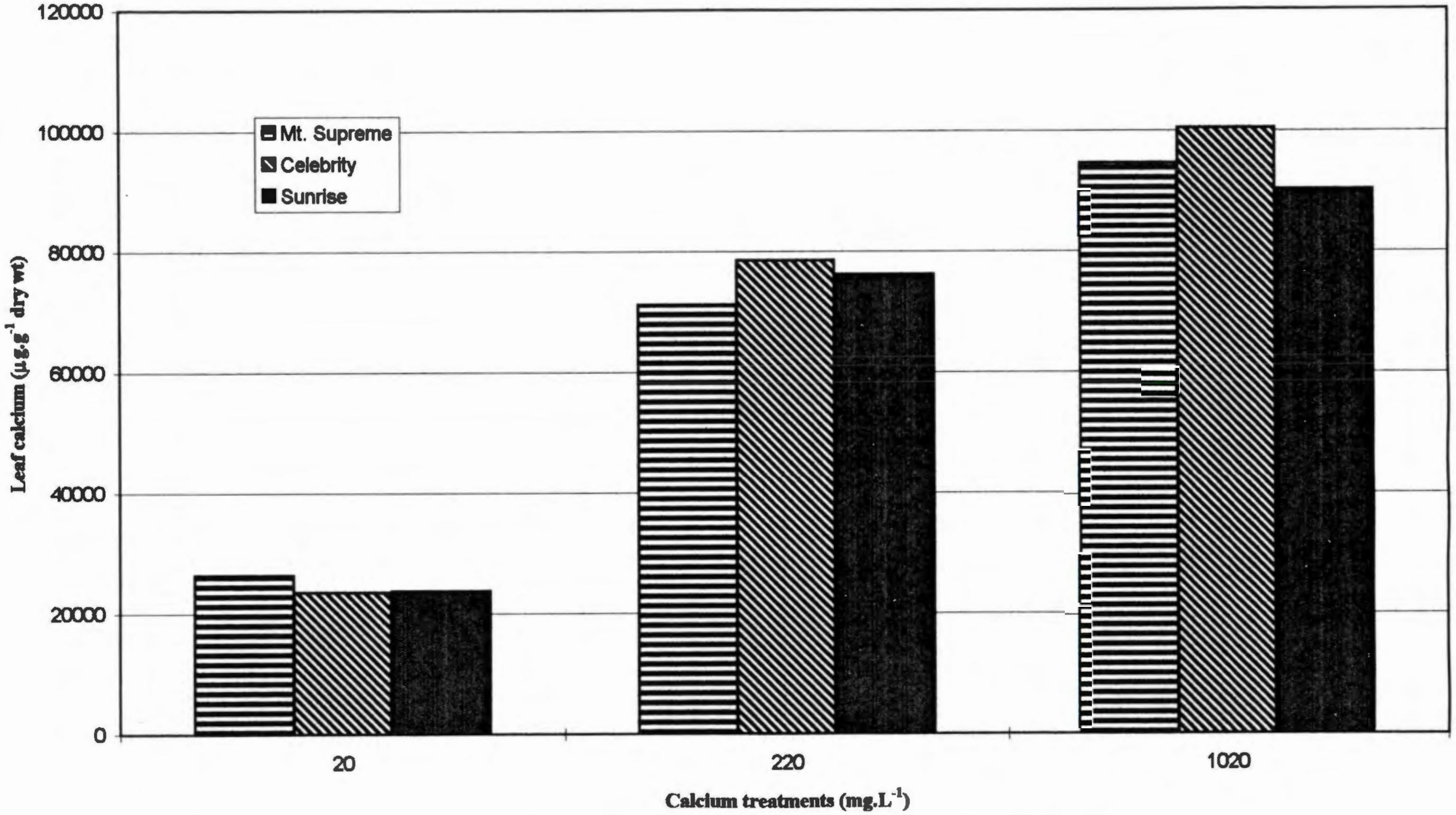

Figure 3. Effect of calcium treatments on tomato leaf calcium concentration in Spring 1996 (Experiment 3).

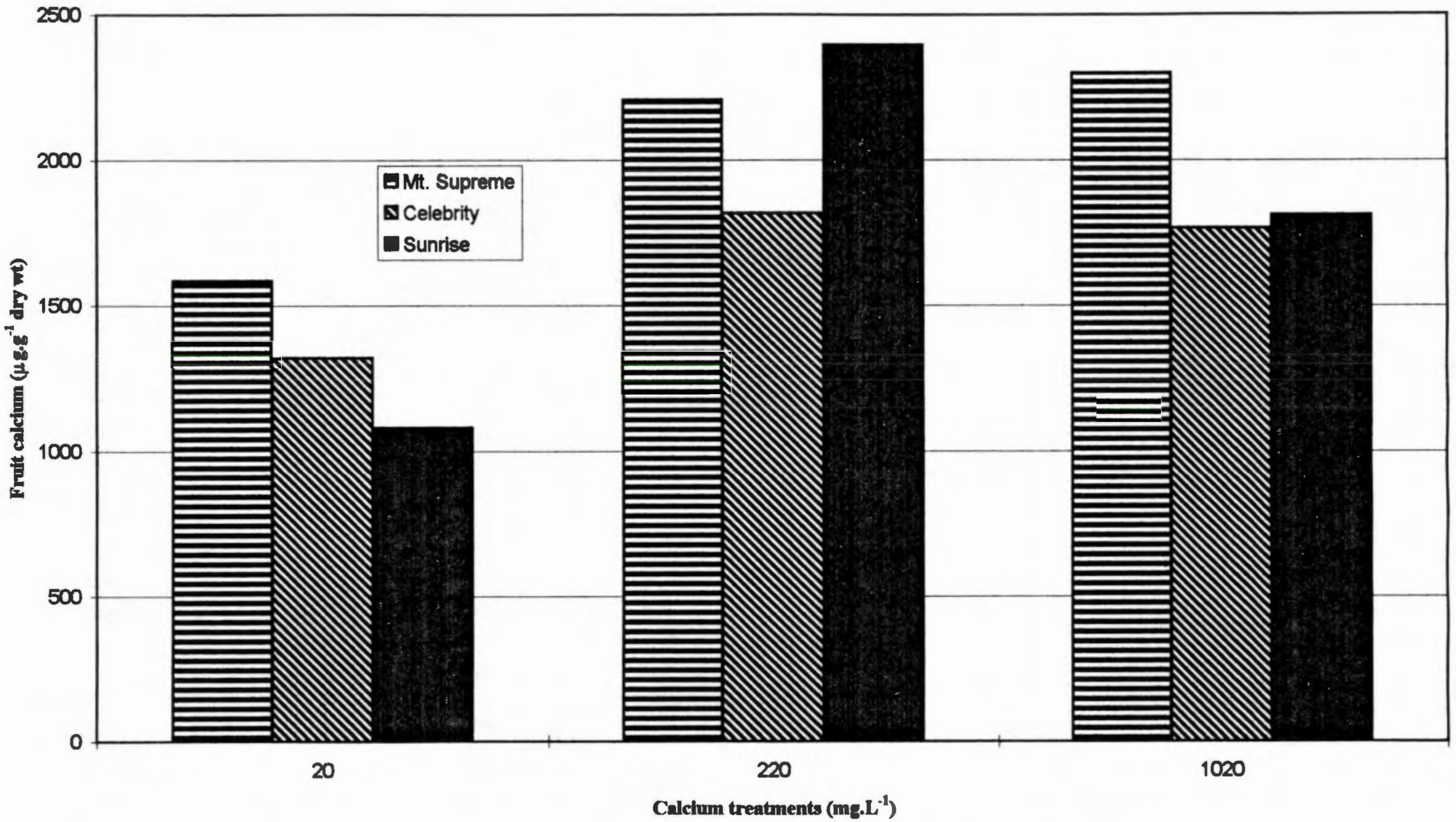

Figure 4. Effect of calcium treatments on tomato fruit calcium concentration in Fall 1995 (Experiment 1).

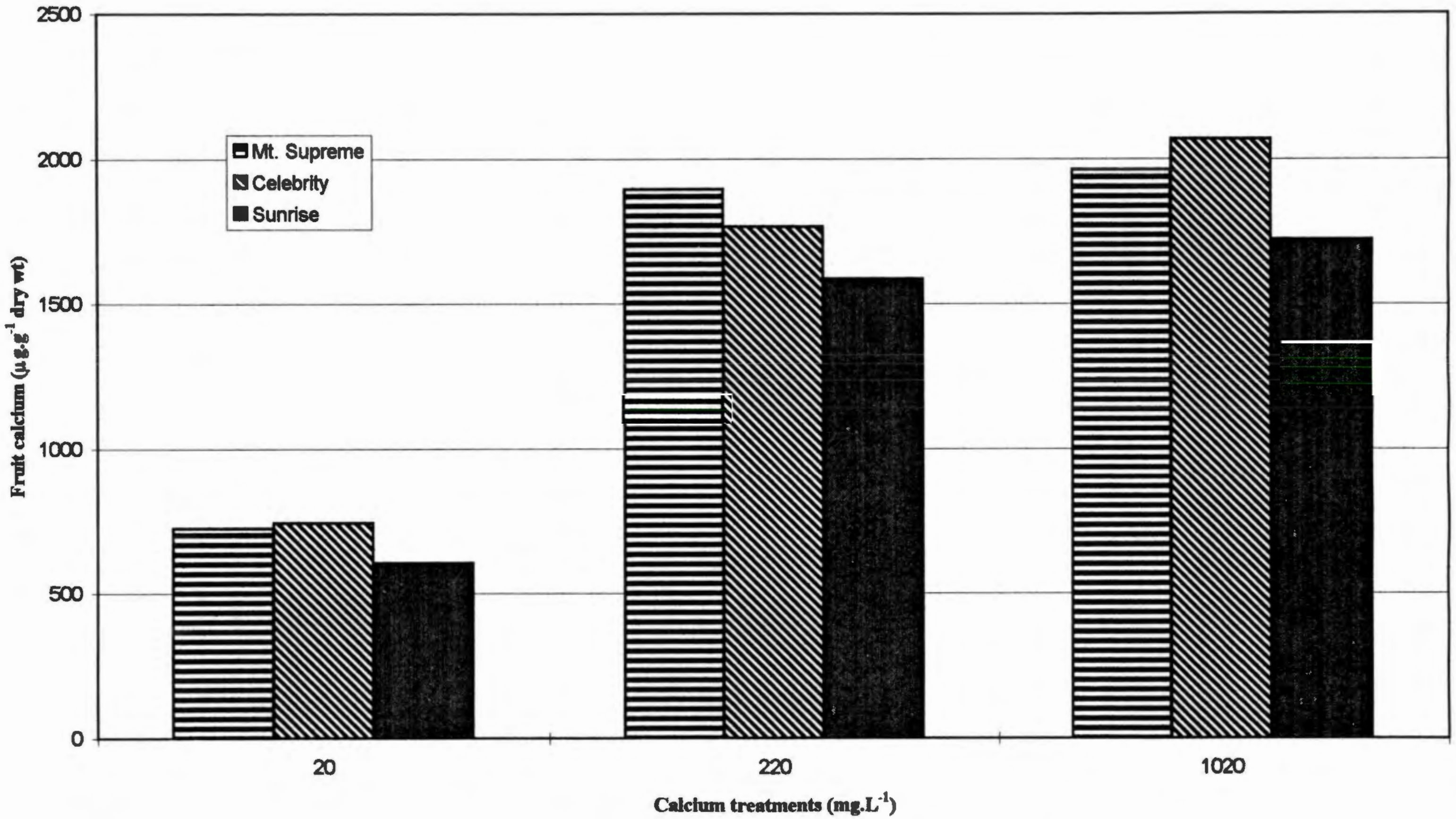

Figure 5. Effect of calcium treatments on tomato fruit calcium concentration in Spring 1996 (Experiment 2).

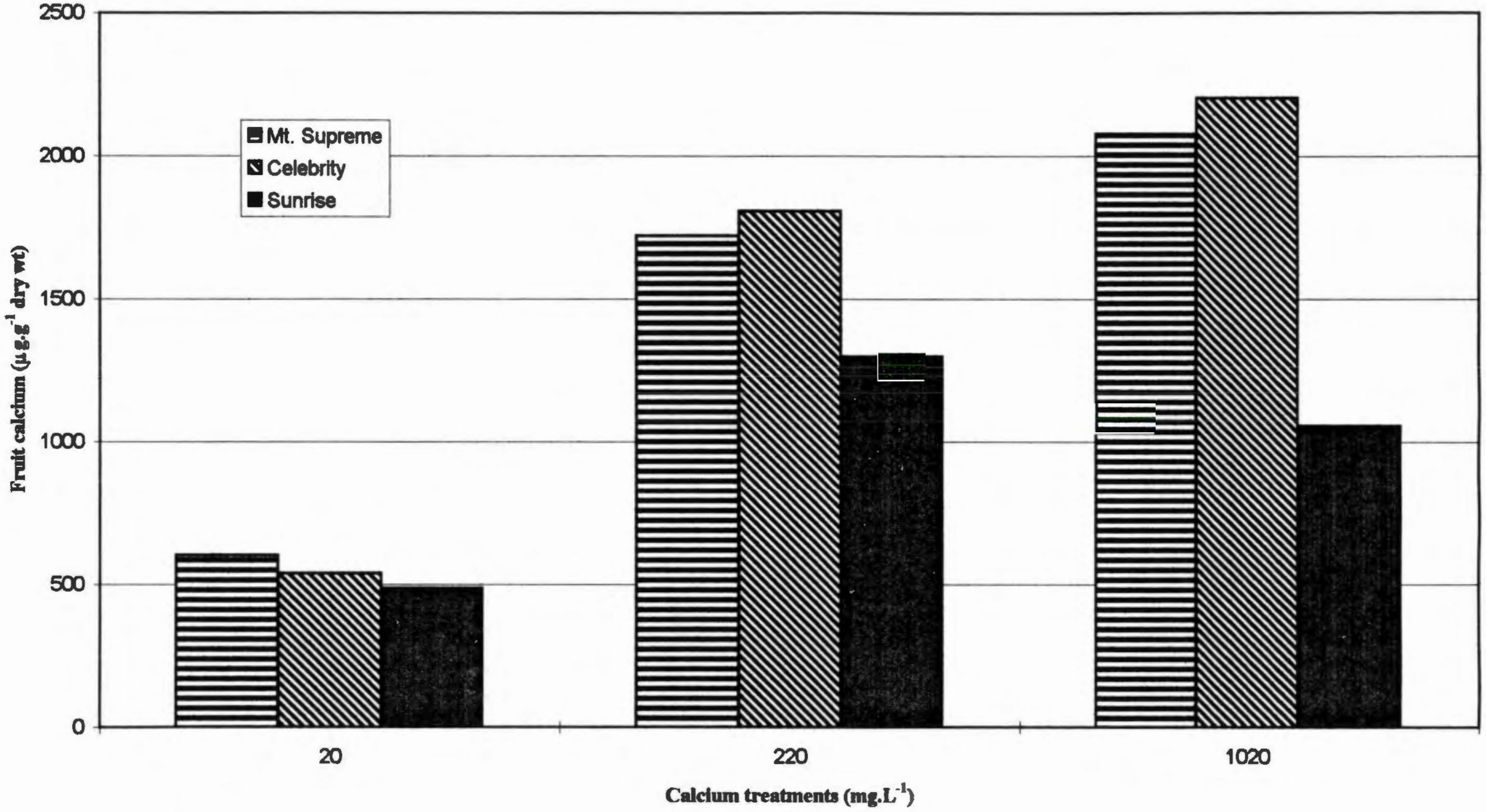

Figure 6. Effect of calcium treatments on tomato fruit calcium concentration in Spring 1996 (Experiment 3).

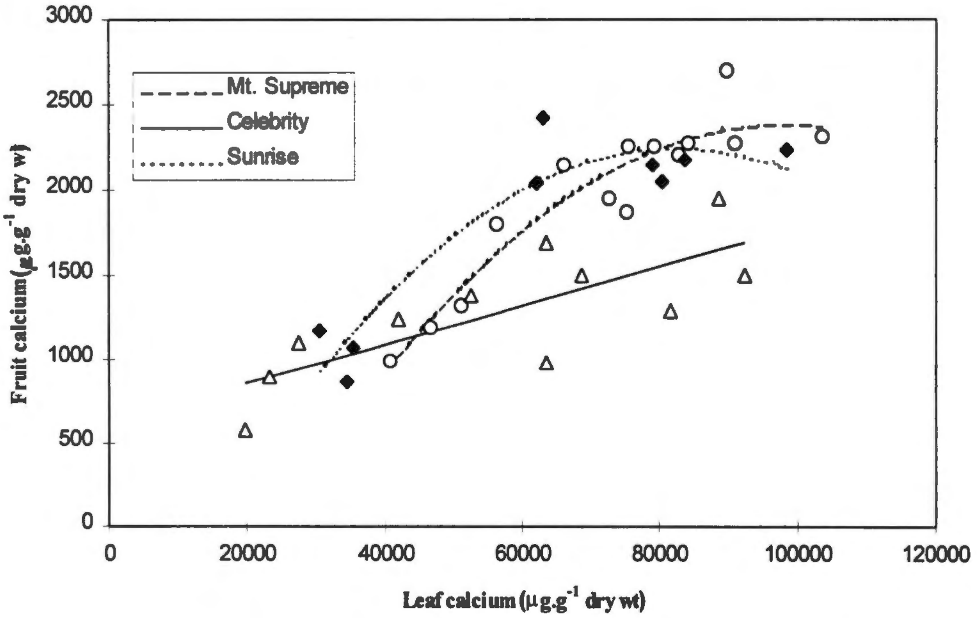

Figure 7. Relationship between the leaf and fruit calcium concentration in three tomato cultivars in Fall 1995 (Experiment 1).

Mt. Supreme (○ - - -): $Y= -1759.835+0.084X-0.00000043X^2$; $R^2=.8916^{**}$
Celebrity (△ ——): $Y= 633.296+0.012X$; $R^2=.5942^{**}$
Sunrise (◆ ......): $Y= -1065.979+0.080X-0.00000049X^2$; $R^2=.8793^{**}$

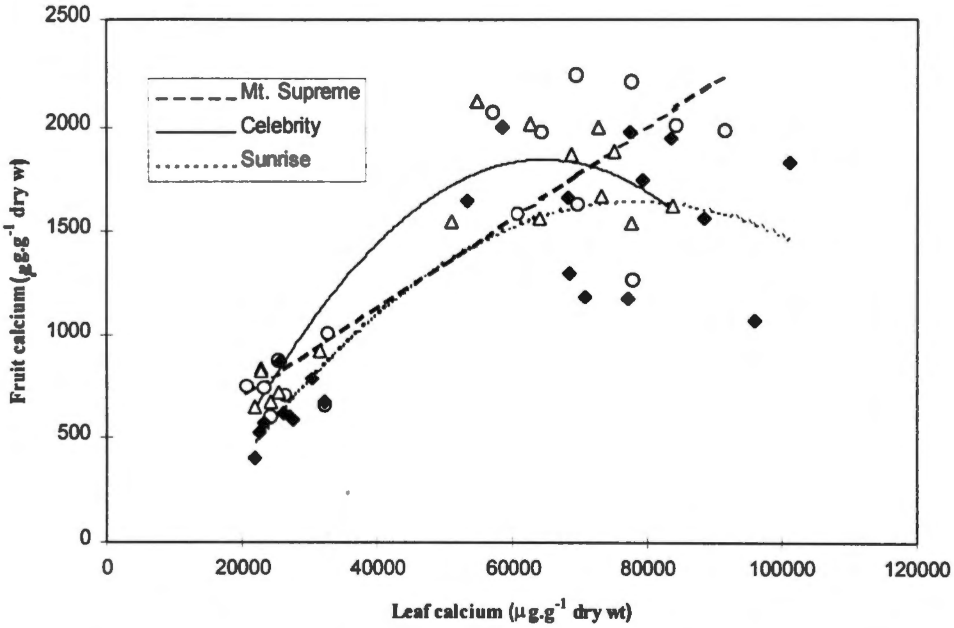

Figure 8. Relationship between leaf and fruit calcium concentration in three tomato cultivars in Spring 1996 (Experiment 2).

Mt. Supreme (○ - - -): Y= 521.430+0.059X; R^2=0.7813*
Celebrity (△ —): Y= -916.908+0.085X-0.7·$10^{-6}X^2$; R^2=0.8789**
Sunrise (◆ ......): Y= -605226+0.057X-0.4·$10^{-6}X^2$; R^2=0.7271**

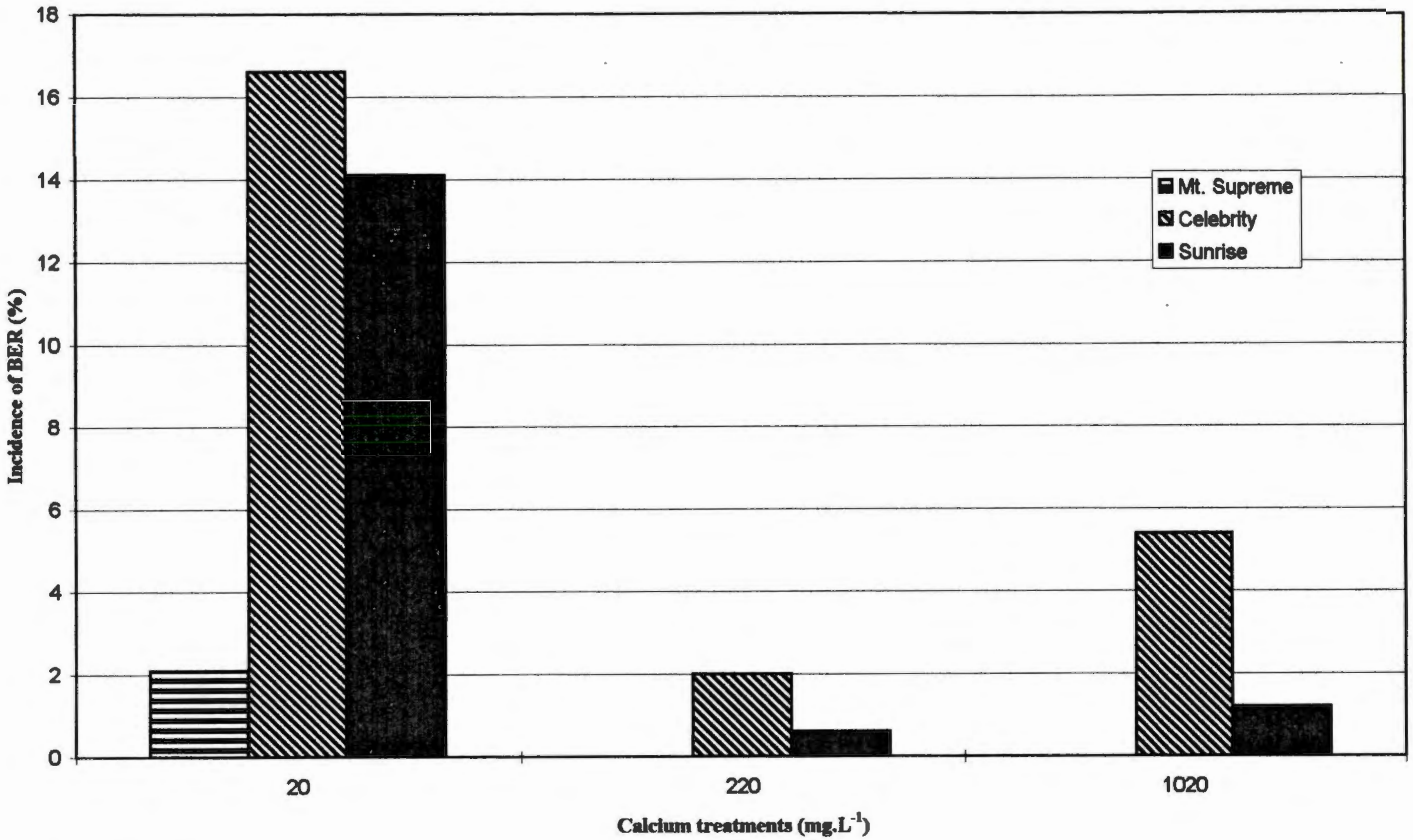

Figure 9. Effect of calcium treatments on incidence of BER in Fall 1995 (Experiment 1).

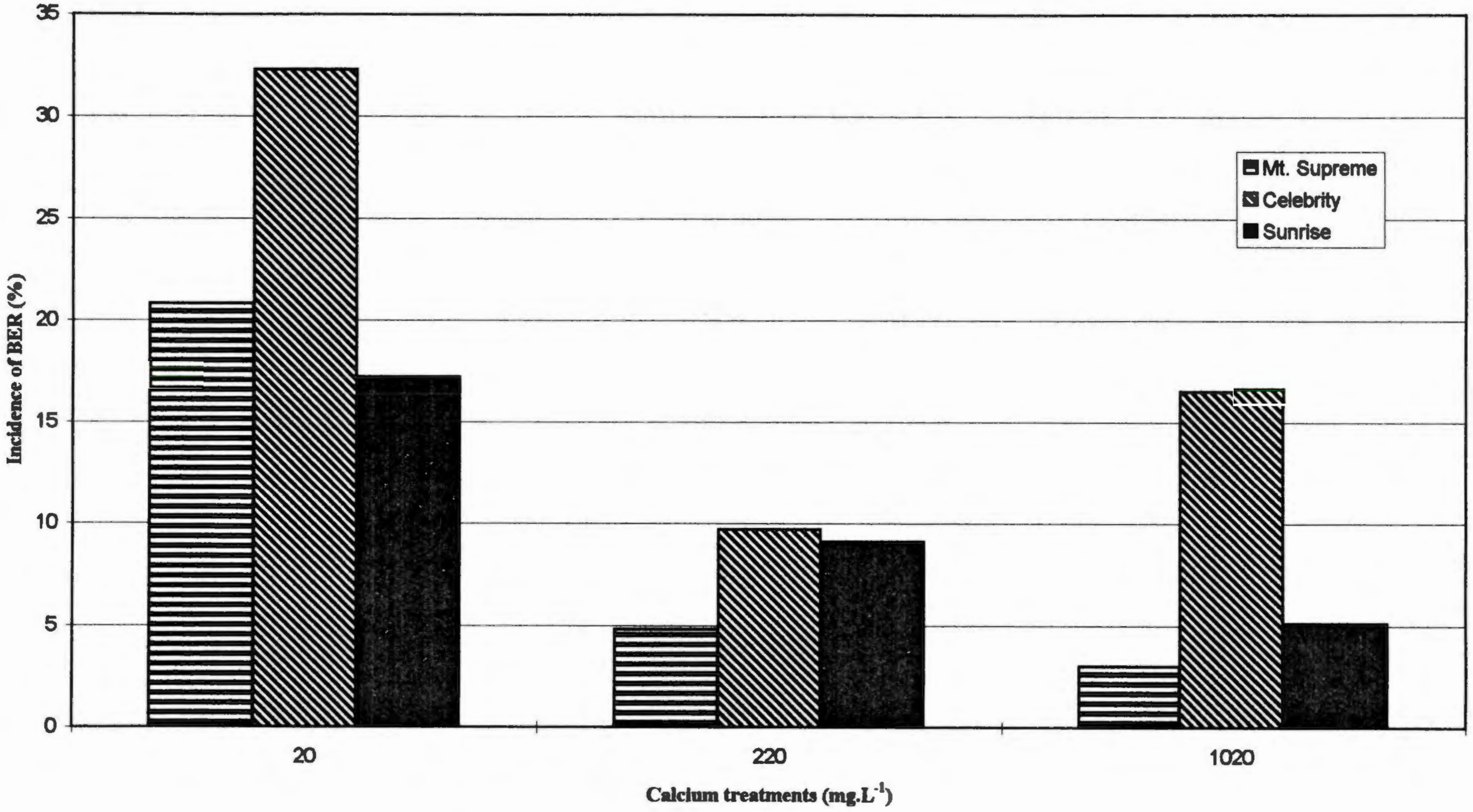

Figure 10. Effect of calcium treatments on incidence of BER in Spring 1996 (Experiment 2).

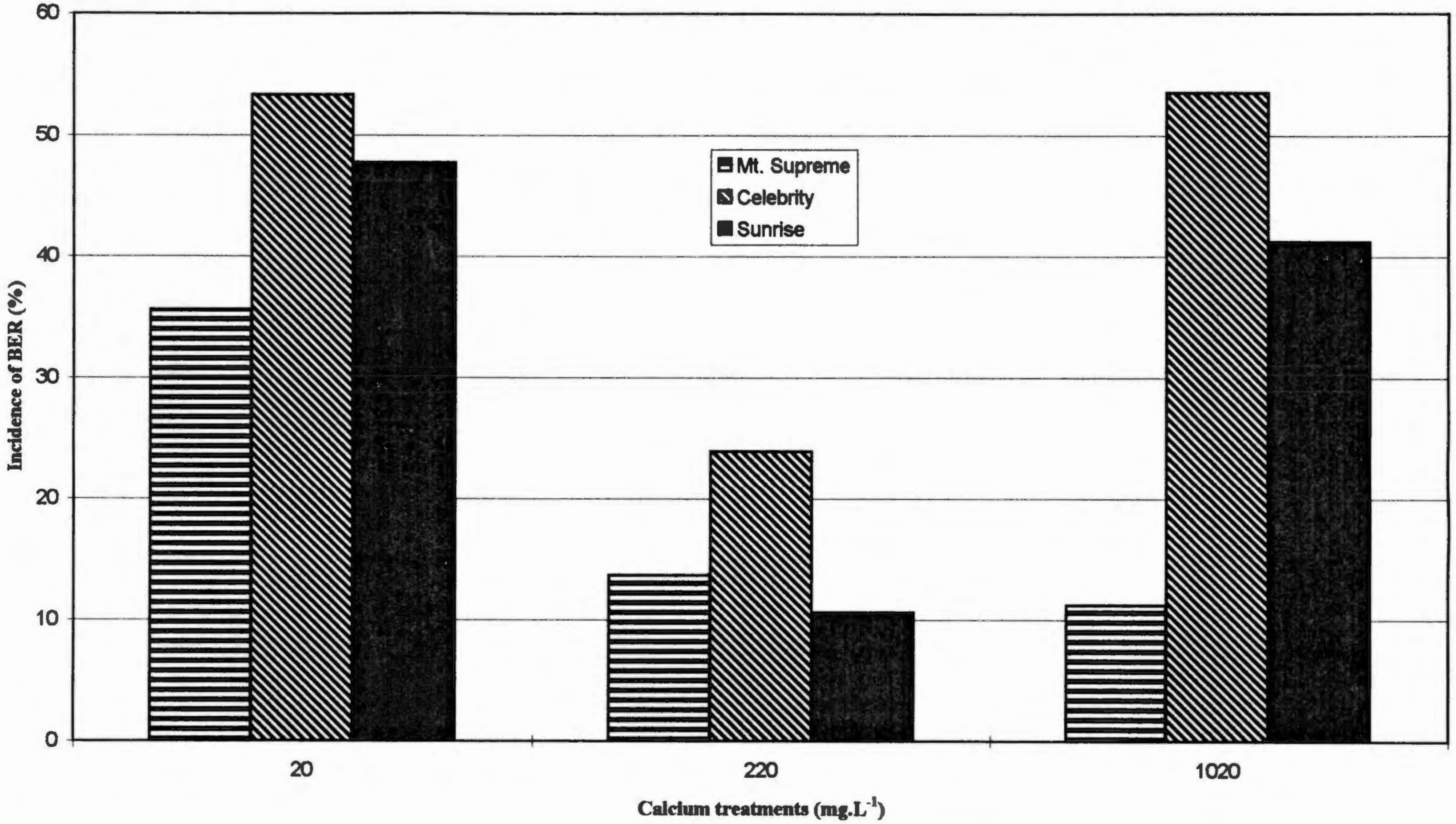

Figure 11. Effect of calcium treatments on incidence of BER in Spring 1996 (Experiment 3).

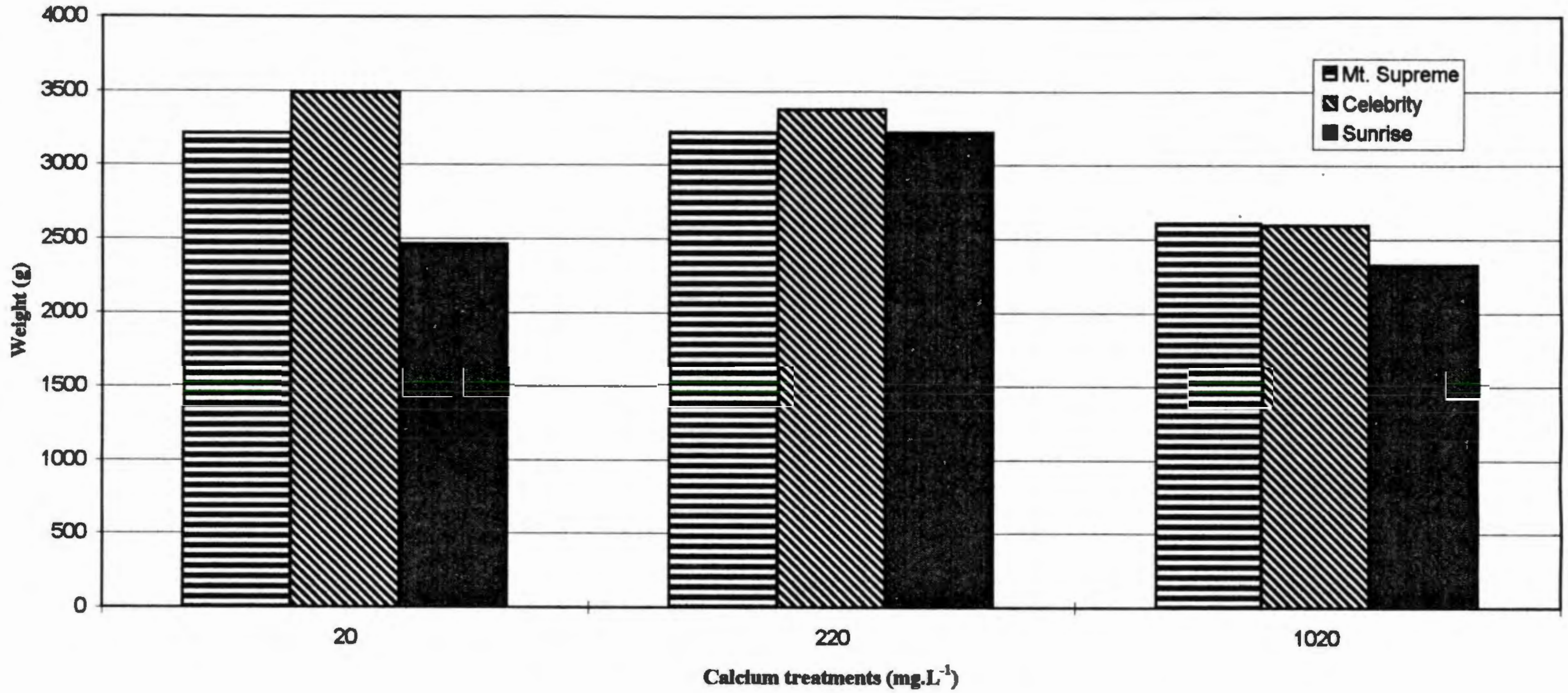

Figure 12. Effect of calcium treatments on total weight of marketable tomato fruit per plant in Fall 1995 (Experiment 1).

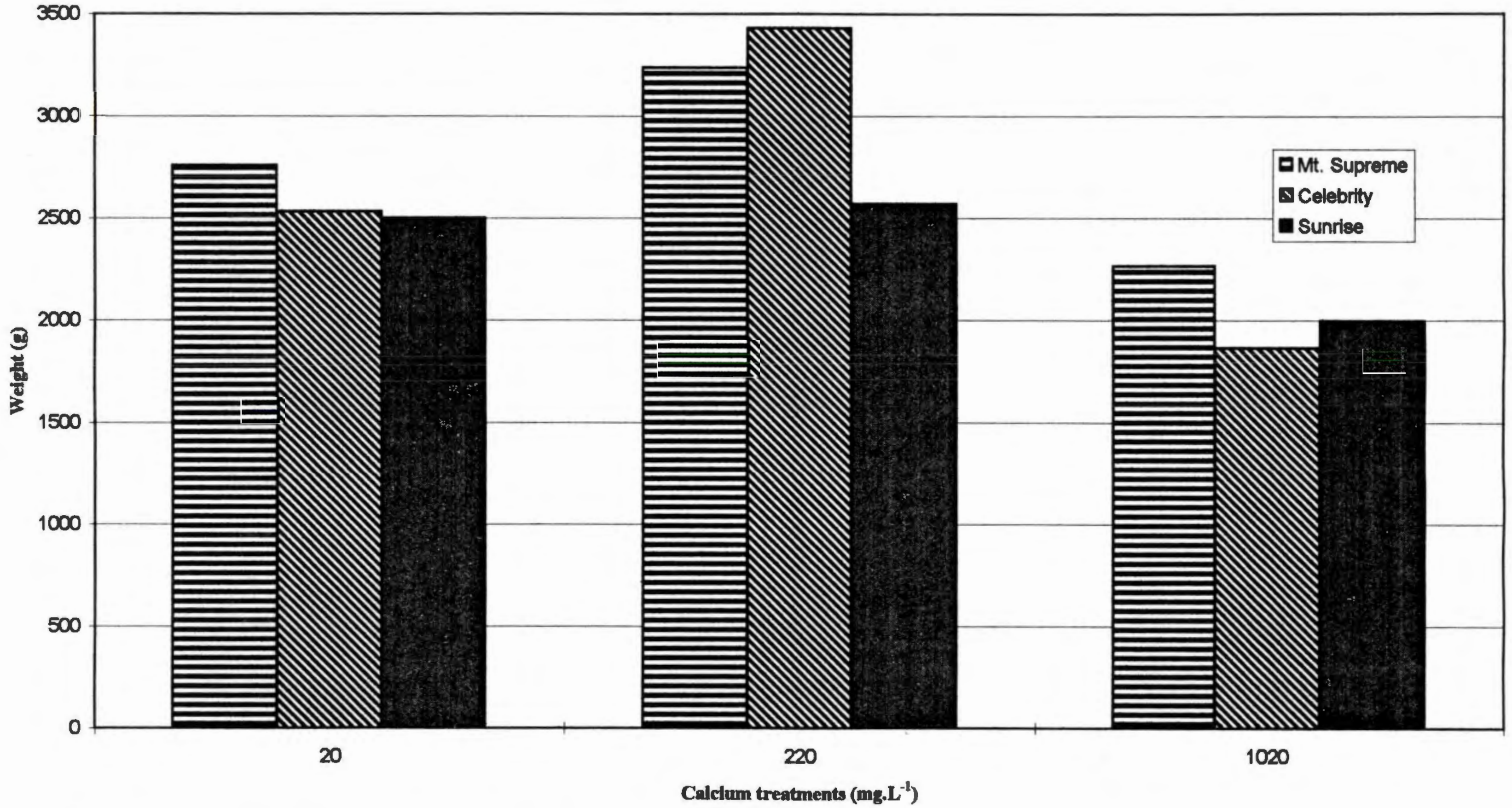

Figure 13. Effect of calcium treatments on total weight of marketable tomato fruit per plant in Spring 1996 (Experiment 2).

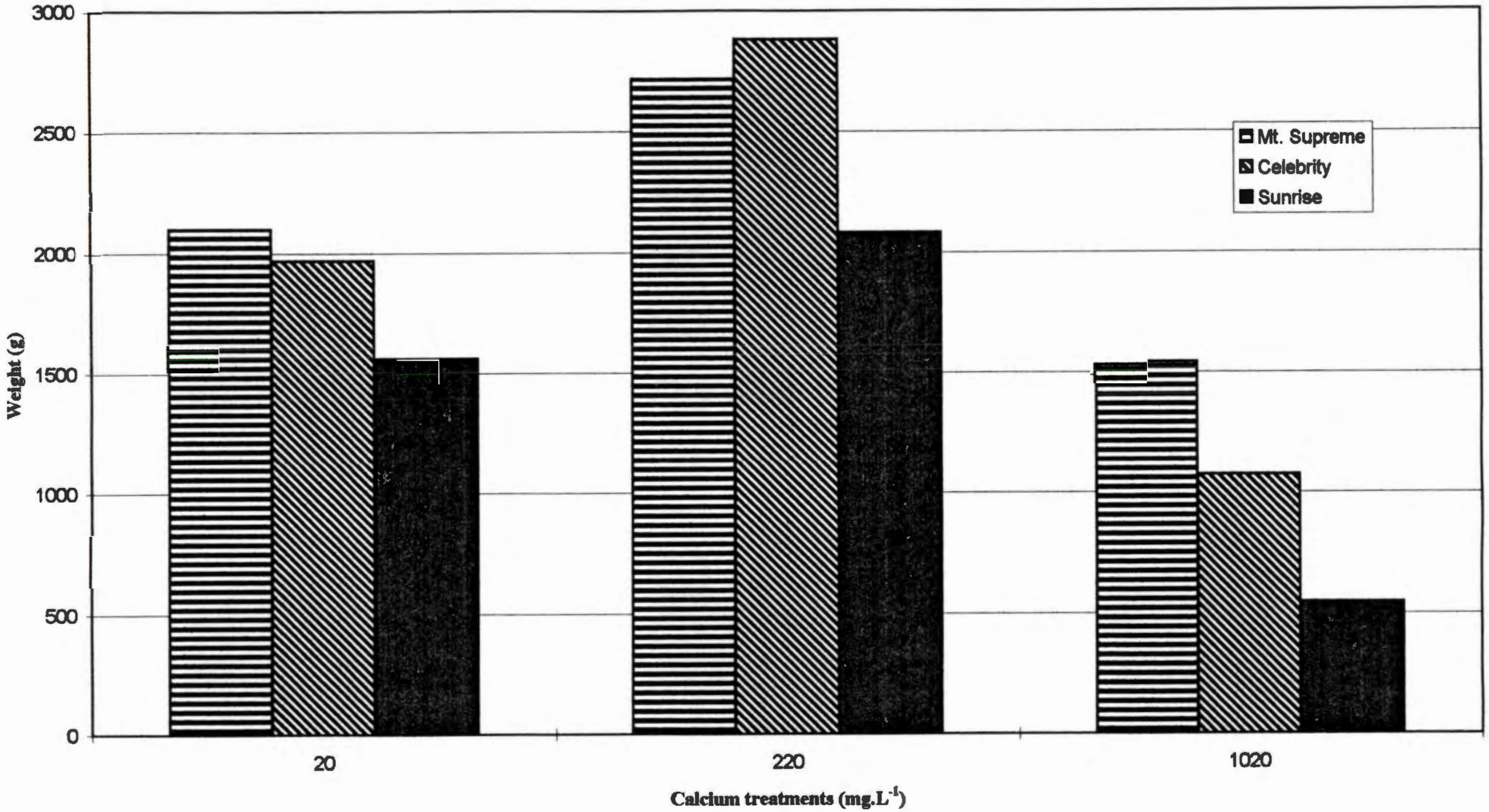

Figure 14. Effect of calcium treatments on total weight of marketable tomato fruit per plant in Spring 1996 (Experiment 3).

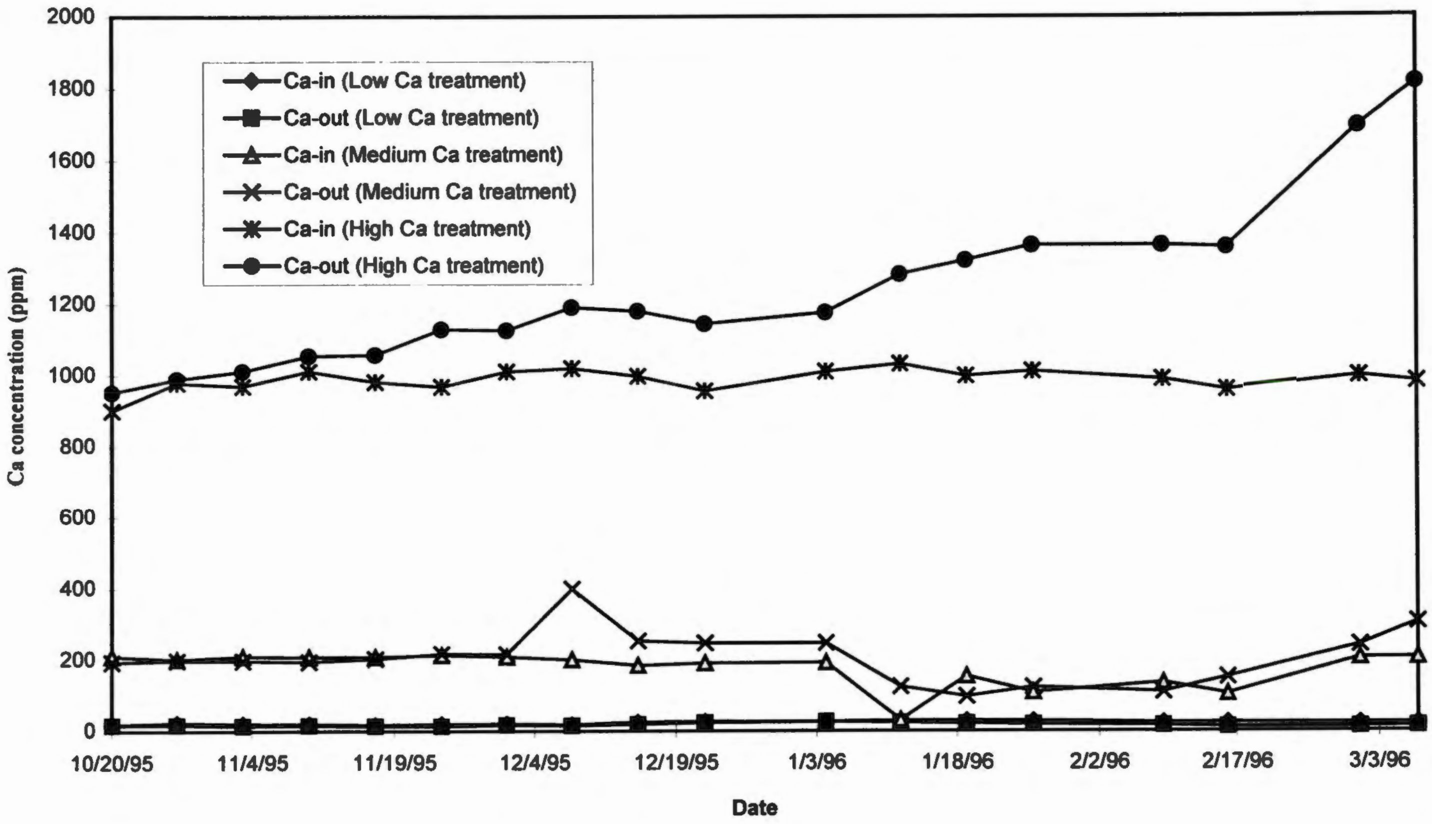

Figure 15. Calcium concentration in solution added over time in Fall 1995 (Experiment 1).

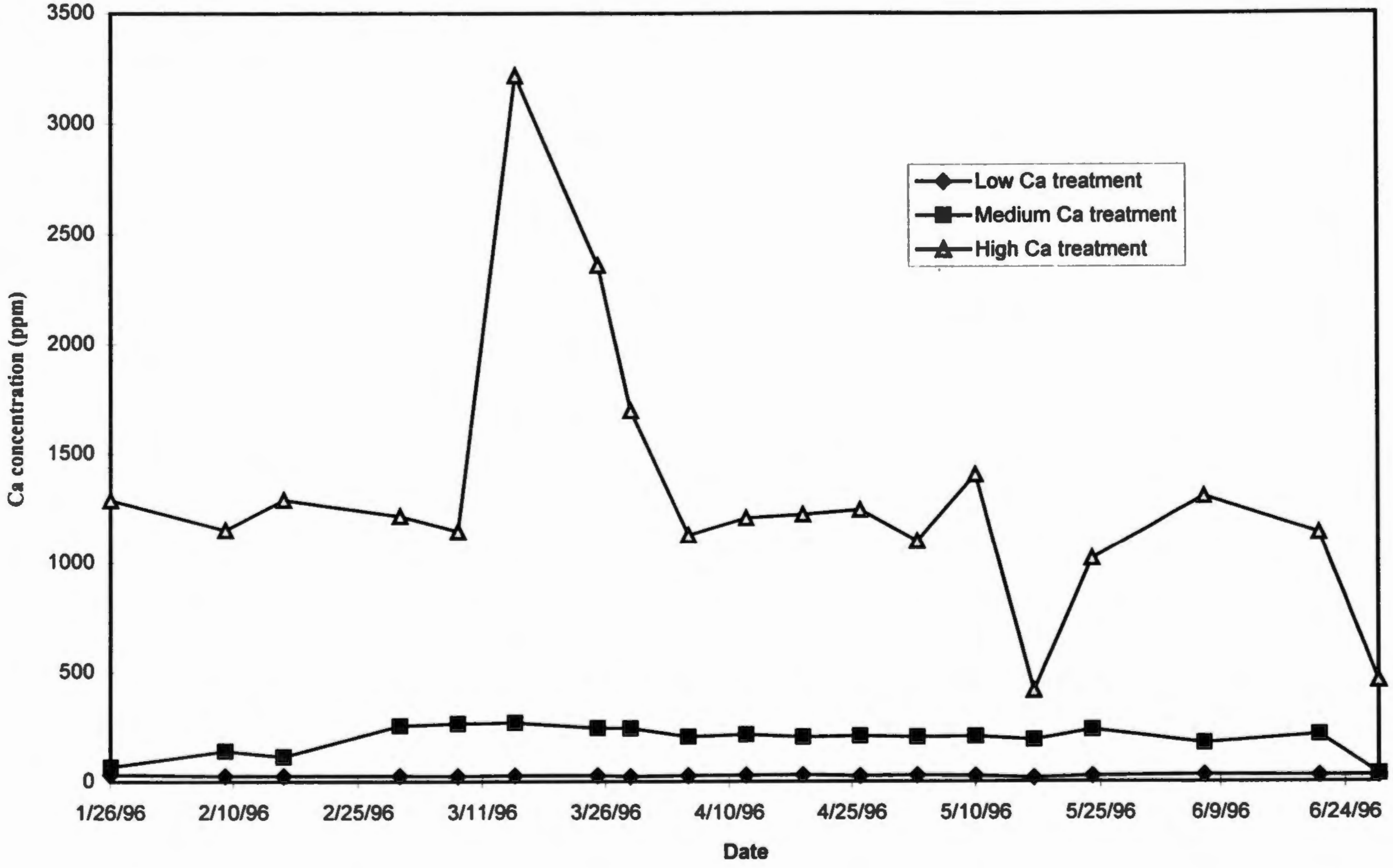

Figure 16. Calcium concentration in solution added over time in Spring 1996 (Experiment 2).

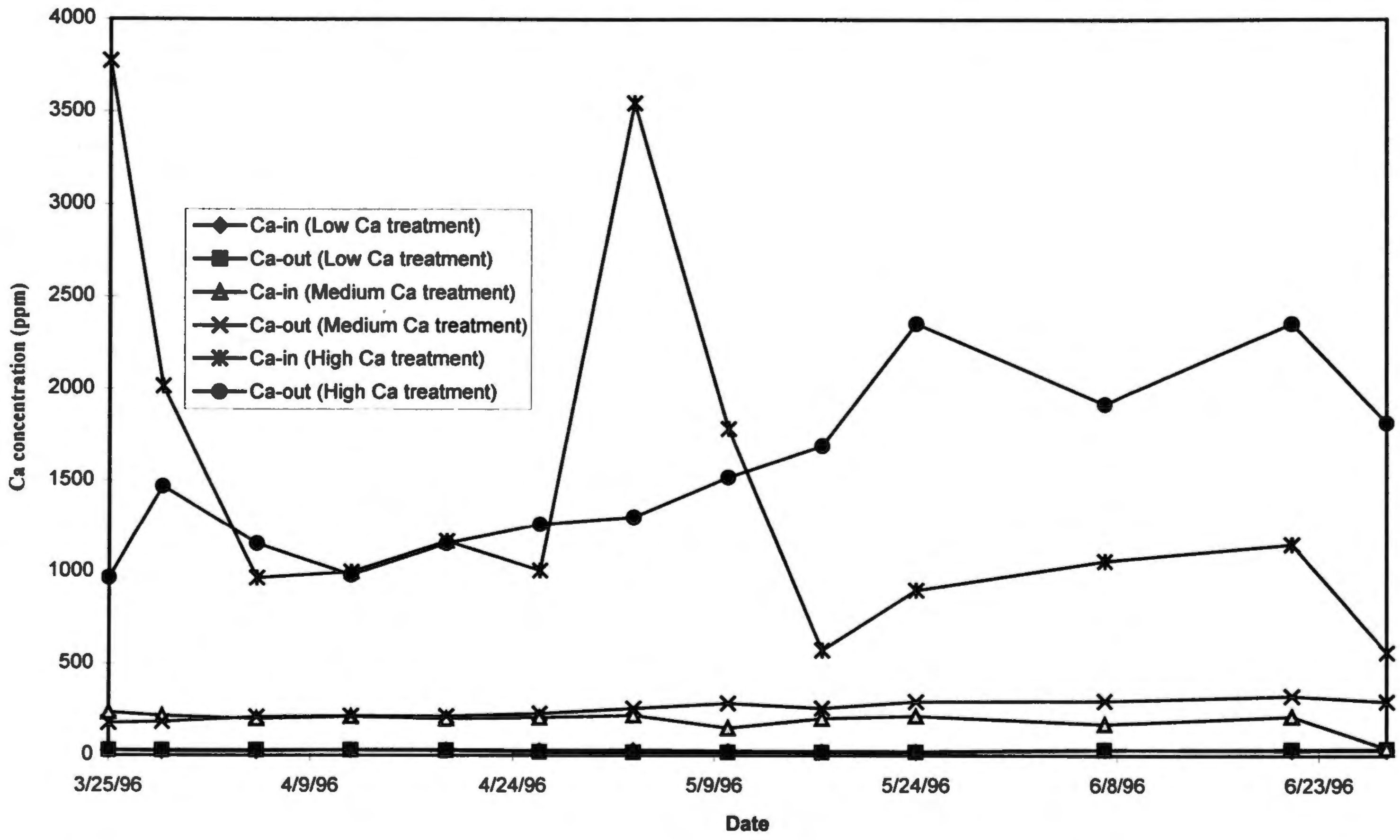

Figure 17. Calcium concentration in solution added over time in Spring 1996 (Experiment 3).

Appendix C

Analysis of Variance

Table 13. Analysis of variance for nutrients of tomato leaf in Fall 1995 (Prob. > F) (Experiment 1)

Sources	Variables[z]					
	LeafCa	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Block	0.6864	0.5985	0.2661	0.5543	0.0585	0.1878
Rep(Block)	0.4102	0.2381	0.7286	0.4845	0.1488	0.5451
Ca treatment (T)	0.0001	0.0001	0.0030	0.0001	0.0001	0.0026
Cultivars (C)	0.2368	0.0036	0.0237	0.0072	0.0001	0.0001
T * C	0.6303	0.6493	0.7867	0.0798	0.0004	0.8193

[z] Leaf Ca= leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration;

Table 14. Analysis of variance for nutrients of tomato fruit in Fall 1995 (Prob. > F) (Experiment 1)

Sources	Variables[z]					
	Fruit Ca	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Block	0.2363	0.5071	0.7635	0.9856	0.5570	0.8825
Rep(Block)	0.4652	0.3829	0.9297	0.7121	0.9089	0.9677
Ca treatment (T)	0.0002	0.2969	0.0777	0.0001	0.0703	0.0001
Cultivars (C)	0.0881	0.1986	0.0049	0.0017	0.0001	0.0001
T * C	0.3661	0.7156	0.3511	0.8704	0.5226	0.8914

[z] Fruit Ca=fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 15. Analysis of variance for tomato yield components in Fall 1995 (Prob. > F) (Experiment 1)

Sources	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfruwe
Block	0.6831	0.8171	0.5984	0.2466	0.3645	0.4670
Rep(Block)	0.3330	0.1095	0.0406	0.9861	0.8422	0.1302
Ca treatment (T)	0.0001	0.0113	0.0656	0.0040	0.3663	0.0010
Cultivars (C)	0.1418	0.0101	0.0001	0.1022	0.0064	0.0003
T * C	0.8289	0.6845	0.4693	0.4722	0.8847	0.6636

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe=marketable fruit weight; Avmkfruwe=the average marketable fruit weight.

Table 16. Analysis of variance for tomato fruit disorders in Fall 1995 (Prob. > F) (Experiment 1)

Sources	Variables[z]		
	BER	Cracking	Catface
Block	0.0933	0.7138	0.1185
Rep(Block)	0.8944	0.1384	0.1033
Ca treatment (T)	0.0001	0.0052	0.7691
Cultivars (C)	0.0020	0.0019	0.2723
T * C	0.0698	0.0680	0.0828

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.

Table 17. Analysis of variance for nutrients of tomato leaf in Spring 1996 (Prob. > F) (Experiment 2)

Sources	Variables[z]							
	1stleafCa	5thleafCa	Leaf Ca	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Block	0.7057	0.0128	0.0315	0.2437	0.0001	0.5088	0.0180	0.6923
Rep(Block)	0.2242	0.1821	0.4244	0.6578	0.3578	0.4070	0.0399	0.5433
Subrep(Rep)	0.0595	0.6747	0.1651	0.0677	0.8273	0.2668	0.7301	0.0761
Ca treatment (T)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cultivars (C)	0.9656	0.0797	0.6091	0.5069	0.0163	0.0176	0.0001	0.0001
T * C	0.2496	0.6370	0.3531	0.9213	0.1349	0.6677	0.6241	0.9207

[z] 1stleafCa=calcium concentration in the leaf above the first flower cluster; 5thleafCa=calcium concentration in the leaf above the fifthflower cluster; Leaf Ca=leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 18. Analysis of variance for nutrients of tomato fruit in Spring 1996 (Prob. > F) (Experiment 2)

Sources	Variables[z]						
	1stfruitCa	FruitCa	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Block	0.8174	0.8485	0.2486	0.0391	0.3634	0.5672	0.7595
Rep(Block)	0.6016	0.2969	0.2749	0.2790	0.6495	0.8096	0.6703
Subrep(Rep)	0.7132	0.3789	0.7809	0.5464	0.5023	0.7403	0.2411
Ca treatment (T)	0.0001	0.0001	0.1478	0.1922	0.0001	0.0001	0.0001
Cultivars (C)	0.0036	0.0006	0.6689	0.0461	0.0875	0.0117	0.0001
T * C	0.3801	0.5673	0.9350	0.0742	0.0073	0.1461	0.0004

[z] 1stfruitCa=calcium concentration in the first cluster fruit; Fruit Ca=fruit calcium concentration; Fruit B=fruit boron concentration; Fruit K=fruit potassium concentration; Fruit Mg=fruit magnesium concentration; Fruit P=fruit phosphorous concentration; Fruit S=fruit sulfur concentration.

Table 19. Analysis of variance for tomato yield components in Spring 1996 (Prob. > F) (Experiment 2)

Sources	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfruwe
Block	0.9901	0.6112	0.7120	0.9927	0.8137	0.6779
Rep(Block)	0.0853	0.2230	0.2704	0.2567	0.6511	0.0170
Subrep(Rep)	0.5494	0.8029	0.8509	0.9590	0.8538	0.7029
Ca treatment (T)	0.0001	0.0005	0.0001	0.0001	0.0017	0.0001
Cultivars (C)	0.0004	0.0001	0.0001	0.0288	0.0001	0.0001
T * C	0.2341	0.2191	0.0006	0.0802	0.6341	0.0491

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe = marketable fruit weight; Avmkfruwe=the average marketable fruit weight.

Table 20. Analysis of variance for tomato fruit disorders in Spring 1996 (Prob. > F) (Experiment 2)

Sources	Variables[z]		
	BER	Cracking	Catface
Block	0.1177	0.5216	0.0848
Rep(Block)	0.1466	0.7502	0.1049
Subrep(Rep)	0.0950	0.9659	0.8077
Ca treatment (T)	0.0001	0.0002	0.1540
Cultivars (C)	0.0003	0.0003	0.0003
T * C	0.3205	0.0007	0.1735

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface

Table 21. Analysis of variance for nutrients of tomato leaf in Spring 1996 (Prob. > F) (Experiment 3)

Sources	Variables[z]							
	1stleafCa	5thleafCa	LeafCa	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Block	0.2763	0.0696	0.1721	0.9443	0.2947	0.1905	0.5053	0.5093
Rep(Block)	0.8137	0.7965	0.8837	0.9938	0.4170	0.8434	0.9219	0.8564
Ca treatment (T)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Cultivars (C)	0.2921	0.4887	0.4952	0.5153	0.0211	0.2644	0.0323	0.0233
T * C	0.4746	0.5381	0.5805	0.3964	0.2269	0.4852	0.3848	0.0885

[z] 1stleafCa=calcium concentration in the leaf above the first flower cluster; 5thleafCa=calcium concentration in the leaf above the fifth flower cluster; Leaf Ca=leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 22. Analysis of variance for nutrients of tomato fruit in Spring 1996 (Prob. > F) (Experiment 3)

Sources	Variables[z]							
	1stfruitCa	3rdfruitCa	Fruit Ca	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Block	0.0890	0.2232	0.0035	0.1161	0.7475	0.3288	0.6962	0.7032
Rep(Block)	0.6026	0.5083	0.2939	0.4468	0.1616	0.6905	0.9095	0.2408
Ca treatment (T)	0.0001	0.0001	0.0001	0.1316	0.8793	0.0001	0.0001	0.0001
Cultivars (C)	0.0007	0.2753	0.0001	0.1762	0.0112	0.1761	0.0024	0.0001
T * C	0.2492	0.1397	0.0004	0.5029	0.2258	0.0577	0.0826	0.0130

[z] 1stleafCa=calcium concentration in the leaf above the first flower cluster; 5thleafCa=calcium concentration in the leaf above the fifth flower cluster; Leaf Ca=leaf calcium concentration; Leaf B=leaf boron concentration; Leaf K=leaf potassium concentration; Leaf Mg=leaf magnesium concentration; Leaf P=leaf phosphorous concentration; Leaf S=leaf sulfur concentration.

Table 23. Analysis of variance for tomato yield components in Spring 1996 (Prob. > F) (Experiment 3)

Sources	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfru we
Block	0.0553	0.0201	0.4436	0.0392	0.0287	0.8313
Rep(Block)	0.7860	0.5016	0.6975	0.2741	0.3110	0.5134
Ca treatment (T)	0.0001	0.4785	0.0001	0.0001	0.0001	0.0001
Cultivars (C)	0.0001	0.0052	0.1825	0.0004	0.0001	0.0001
T * C	0.1681	0.3473	0.0158	0.5647	0.9595	0.0013

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe=marketable fruit weight; Mkfru#=marketable fruit number; Avmkfruwe=the average marketable fruit weight.

Table 24. Analysis of variance for tomato fruit disorders in Spring 1996 (Prob. > F) (Experiment 3)

Sources	Variables[z]		
	BER	Cracking	Catface
Block	0.9862	0.0001	0.2307
Rep(Block)	0.1180	0.3302	0.5344
Ca treatment (T)	0.0001	0.0240	0.0394
Cultivars (C)	0.0001	0.0022	0.1303
T * C	0.0398	0.3143	0.1441

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.

Appendix D

Tables of probability of greater F values for preplanned treatment

Table 25. Probability of greater F values for preplanned treatment contrast of tomato leaf nutrients in Fall 1995 (Experiment 1)

Contrast	Variables[z]					
	Leaf Ca	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Across cultivars:						
T_1 vs T_2[y]	0.0001	0.0005	0.4779	0.0001	0.0001	0.7635
T_1 vs T_3[y]	0.0001	0.0001	0.0137	0.0001	0.0001	0.0063
Across treatments:						
C_1 vs C_2[x]	0.0941	0.0014	0.3781	0.0020	0.0001	0.0001
C_1 vs C_3[x]	0.5485	0.4673	0.0075	0.2359	0.0028	0.0009
For C_1:						
T_1 vs T_2[y]	0.0066	0.0168	0.6545	0.0001	0.0001	0.5218
T_1 vs T_3[y]	0.0021	0.0046	0.2171	0.0001	0.0001	0.1704
For C_2:						
T_1 vs T_2[y]	0.0015	0.2290	0.7061	0.0001	0.0349	0.9657
T_1 vs T_3[y]	0.0006	0.0021	0.1435	0.0001	0.0001	0.0462
For C_3:						
T_1 vs T_2[y]	0.0289	0.0629	0.2979	0.0001	0.4833	0.8553
T_1 vs T_3[y]	0.0430	0.0015	0.1753	0.0001	0.0043	0.0749
At T_1:						
C_1 vs C_2[x]	0.0188	0.0280	0.4684	0.0305	0.0001	0.0006
C_1 vs C_3[x]	0.0979	0.4072	0.0147	0.2809	0.0014	0.1075
At T_2:						
C_1 vs C_2[x]	0.4943	0.6413	0.2600	0.0775	0.0568	0.0006
C_1 vs C_3[x]	0.9436	0.5178	0.2082	0.8092	0.8731	0.0323
At T_3:						
C_1 vs C_2[x]	0.6307	0.0087	0.7583	0.6236	0.1654	0.0003
C_1 vs C_3[x]	0.6978	0.3874	0.0719	0.8323	0.9848	0.0900

[z] Leaf Ca=the average leaf calcium concentration; Leaf B=the average leaf boron concentration; Leaf K=the average leaf potassium concentration; Leaf Mg=the average leaf magnesium concentration; Leaf P=the average leaf phosphorous concentration; Leaf S=the average leaf sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 26. Probability of greater F values for preplanned treatment contrast of tomato leaf nutrients in Spring 1996 (Experiment 2)

Contrast	Variables[z]							
	1stleaf Ca	5thleaf Ca	Leaf Ca	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Across cultivars:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0192
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Across treatments:								
C_1 vs C_2[x]	0.7921	0.0468	0.3757	0.2496	0.0079	0.0051	0.0001	0.0001
C_1 vs C_3[x]	0.8851	0.0529	0.3999	0.6621	0.6850	0.3022	0.3751	0.0083
For C_1:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0144	0.0012	0.0001	0.0009	0.2521
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0005	0.0001	0.0001	0.0011
For C_2:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0078	0.0001	0.0001	0.0014	0.0771
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0014
For C_3:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0844	0.1190	0.0001	0.3572	0.2329
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0007	0.0001
At T_1:								
C_1 vs C_2[x]	0.1234	0.3489	0.6218	0.4641	0.4882	0.0841	0.0610	0.0002
C_1 vs C_3[x]	0.5435	0.2610	0.7130	0.7735	0.4174	0.5436	0.7941	0.0994
At T_2:								
C_1 vs C_2[x]	0.4189	0.3876	0.8401	0.9907	0.0536	0.0068	0.0071	0.0001
C_1 vs C_3[x]	0.2475	0.3868	0.9889	0.7406	0.1447	0.2043	0.0311	0.1291
At T_3:								
C_1 vs C_2[x]	0.3079	0.0630	0.0755	0.1544	0.0357	0.1302	0.0016	0.0015
C_1 vs C_3[x]	0.6641	0.2298	0.4150	0.2826	0.1739	0.5919	0.7649	0.0912

[z] 1stleaf Ca=calcium concentration in the leaf above the first flower cluster; 5thleaf Ca=calcium concentration in the leaf above the fifth flower cluster; Leaf Ca=the average leaf calcium concentration; Leaf B=the average leaf boron concentration; Leaf K=the average leaf potassium concentration; Leaf Mg=the average leaf magnesium concentration; Leaf P=the average leaf phosphorous concentration; Leaf S=the average leaf sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 27. Probability of greater F values for preplanned treatment contrast of tomato leaf nutrients in Spring 1996 (Experiment 3)

Contrast	Variables[z]							
	1stleaf Ca	5thleaf Ca	Leaf Ca	Leaf B	Leaf K	Leaf Mg	Leaf P	Leaf S
Across cultivars:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004	0.1042
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Across treatments:								
C_1 vs C_2[x]	0.2657	0.5426	0.3398	0.3445	0.6856	0.1498	0.0212	0.0146
C_1 vs C_3[x]	0.6844	0.5434	0.8836	0.9333	0.0102	0.1633	0.9507	0.9032
For C_1:								
T_1 vs T_2[y]	0.0001	0.0002	0.0006	0.0012	0.0001	0.0001	0.0158	0.0317
T_1 vs T_3[y]	0.0001	0.0001	0.0003	0.0001	0.0001	0.0001	0.0001	0.0001
For C_2:								
T_1 vs T_2[y]	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0715	0.5288
T_1 vs T_3[y]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0166
For C_3:								
T_1 vs T_2[y]	0.0001	0.0038	0.0060	0.0018	0.0001	0.0001	0.0551	0.3677
T_1 vs T_3[y]	0.0001	0.0003	0.0010	0.0001	0.0001	0.0001	0.0002	0.0001
At T_1:								
C_1 vs C_2[x]	0.2380	0.3152	0.2685	0.1340	0.1905	0.1522	0.1130	0.0079
C_1 vs C_3[x]	0.5629	0.6020	0.4474	0.9180	0.2024	0.2253	0.6747	0.7417
At T_2:								
C_1 vs C_2[x]	0.4745	0.2121	0.3556	0.2302	0.7698	0.8456	0.0970	0.8279
C_1 vs C_3[x]	0.9495	0.5224	0.6823	0.8643	0.0041	0.9752	0.8052	0.2761
At T_3:								
C_1 vs C_2[x]	0.1761	0.5542	0.5990	0.2254	0.9129	0.9735	0.5585	0.3879
C_1 vs C_3[x]	0.6325	0.6127	0.3626	0.9816	0.5655	0.1599	0.2532	0.5144

[z] 1stleaf Ca=calcium concentration in the leaf above the first flower cluster; 5thleaf Ca=calcium concentration in the leaf above the fifth flower cluster; Leaf Ca=the average leaf calcium concentration; Leaf B=the average leaf boron concentration; Leaf K=the average leaf potassium concentration; Leaf Mg=the average leaf magnesium concentration; Leaf P = the average leaf phosphorous concentration; Leaf S = the average leaf sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 28. Probability of greater F values for preplanned treatment contrast of tomato fruit nutrients in Fall 1995 (Experiment 1)

Contrast	Variables[z]					
	Fruit Ca	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Across cultivars:						
T_1 vs T_2[y]	0.0001	0.1298	0.8254	0.0002	0.1049	0.0321
T_1 vs T_3[y]	0.0012	0.2546	0.0463	0.0001	0.0238	0.0001
Across treatments:						
C_1 vs C_2[x]	0.0343	0.0971	0.1452	0.3574	0.0001	0.0001
C_1 vs C_3[x]	0.1451	0.9080	0.0439	0.0060	0.1900	0.8478
For C_1:						
T_1 vs T_2[y]	0.0862	0.6415	0.2443	0.0007	0.0346	0.1396
T_1 vs T_3[y]	0.0270	0.7866	0.8638	0.0006	0.0056	0.0022
For C_2:						
T_1 vs T_2[y]	0.1588	0.9567	0.8387	0.0629	0.3438	0.0357
T_1 vs T_3[y]	0.1660	0.7960	0.0690	0.0308	0.4759	0.0086
For C_3:						
T_1 vs T_2[y]	0.0004	0.0612	0.3462	0.0935	0.8403	0.5179
T_1 vs T_3[y]	0.0388	0.1688	0.0745	0.1526	0.6820	0.1133
At T_1:						
C_1 vs C_2[x]	0.5551	0.3253	0.0516	0.2213	0.0062	0.0806
C_1 vs C_3[x]	0.0755	0.1902	0.5428	0.5978	0.6598	0.8728
At T_2:						
C_1 vs C_2[x]	0.3492	0.3418	0.5804	0.8800	0.1054	0.0305
C_1 vs C_3[x]	0.6082	0.6244	0.0851	0.0371	0.1592	0.6746
At T_3:						
C_1 vs C_2[x]	0.0870	0.3121	0.9294	0.5625	0.0691	0.0093
C_1 vs C_3[x]	0.1219	0.8510	0.0404	0.0338	0.1289	0.7478

[z] Fruit Ca=the average fruit calcium concentration; Fruit B=the average fruit boron concentration; Fruit K=the average fruit potassium concentration; Fruit Mg=the average fruit magnesium concentration; Fruit P=the average fruit phosphorous concentration; Fruit S=the average fruit sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 29. Probability of greater F values for preplanned treatment contrast of tomato fruit nutrients in Spring 1996 (Experiment 2)

Contrast	Variables[z]						
	1stfruit Ca	Fruit Ca	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Across cultivars:							
T_1 vs T_2[y]	0.0001	0.0001	0.2418	0.0712	0.0001	0.0007	0.0001
T_1 vs T_3[y]	0.0001	0.0001	0.3456	0.3620	0.0001	0.0001	0.0001
Across treatments:							
C_1 vs C_2[x]	0.4768	0.9824	0.8597	0.1020	0.5186	0.0043	0.0001
C_1 vs C_3[x]	0.0063	0.0005	0.3853	0.0170	0.0290	0.6669	0.0016
For C_1:							
T_1 vs T_2[y]	0.0001	0.0001	0.3329	0.0235	0.0001	0.3286	0.7346
T_1 vs T_3[y]	0.0001	0.0001	0.1558	0.0009	0.0001	0.0792	0.0687
For C_2:							
T_1 vs T_2[y]	0.0001	0.0001	0.4203	0.7133	0.0001	0.0389	0.0006
T_1 vs T_3[y]	0.0001	0.0001	0.7919	0.9877	0.0001	0.1139	0.0037
For C_3:							
T_1 vs T_2[y]	0.0001	0.0001	0.5653	0.3077	0.0001	0.1215	0.0009
T_1 vs T_3[y]	0.0001	0.0001	0.6577	0.3817	0.0001	0.0011	0.0001
At T_1:							
C_1 vs C_2[x]	0.8527	0.8754	0.5645	0.0032	0.0198	0.6276	0.4466
C_1 vs C_3[x]	0.0052	0.0036	0.6170	0.0013	0.0067	0.6358	0.3701
At T_2:							
C_1 vs C_2[x]	0.3067	0.1275	0.9475	0.2807	0.1650	0.0031	0.0001
C_1 vs C_3[x]	0.1166	0.0038	0.7920	0.0481	0.3476	0.7607	0.0482
At T_3:							
C_1 vs C_2[x]	0.3994	0.9595	0.7677	0.5310	0.4989	0.0296	0.0009
C_1 vs C_3[x]	0.0330	0.0314	0.1929	0.3189	0.3024	0.0185	0.0001

[z] 1stfruit Ca=calcium concentration in the first cluster fruit; Fruit Ca=the average fruit calcium concentration; Fruit B=the average fruit boron concentration; Fruit K=the average fruit potassium concentration; Fruit Mg=the average fruit magnesium concentration; Fruit P=the average fruit phosphorous concentration; Fruit S=the average fruit sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 30. Probability of greater F values for preplanned treatment contrast of tomato fruit nutrients in Spring 1996 (Experiment 3)

Contrast	Variables[z]					
	Fruit Ca	Fruit B	Fruit K	Fruit Mg	Fruit P	Fruit S
Across cultivars:						
T_1 vs T_2[y]	0.0001	0.2073	0.7605	0.0001	0.0001	0.0001
T_1 vs T_3[y]	0.0001	0.3142	0.7920	0.0001	0.0001	0.0001
Across treatments:						
C_1 vs C_2[x]	0.9195	0.1750	0.0564	0.8850	0.0099	0.0001
C_1 vs C_3[x]	0.0001	0.0895	0.0041	0.0768	0.2137	0.5465
For C_1:						
T_1 vs T_2[y]	0.0001	0.5736	0.1485	0.0001	0.0002	0.0001
T_1 vs T_3[y]	0.0001	0.3314	0.0491	0.0001	0.0001	0.0001
For C_2:						
T_1 vs T_2[y]	0.0001	0.2163	0.8709	0.0001	0.0128	0.0001
T_1 vs T_3[y]	0.0001	0.5195	0.4072	0.0001	0.0033	0.0001
For C_3:						
T_1 vs T_2[y]	0.0001	0.2954	0.0626	0.0013	0.6443	0.1182
T_1 vs T_3[y]	0.0240	0.4731	0.5741	0.0007	0.0503	0.0042
At T_1:						
C_1 vs C_2[x]	0.0907	0.0857	0.4232	0.7369	0.0313	0.0003
C_1 vs C_3[x]	0.0151	0.0254	0.4401	0.3198	0.0469	0.0011
At T_2:						
C_1 vs C_2[x]	0.6420	0.9367	0.0200	0.3462	0.1087	0.0109
C_1 vs C_3[x]	0.0104	0.6146	0.0134	0.0527	0.0390	0.1478
At T_3:						
C_1 vs C_2[x]	0.7445	0.3484	0.9722	0.3274	0.1989	0.0098
C_1 vs C_3[x]	0.0042	0.0900	0.1156	0.0860	0.1124	0.3725

[z] Fruit Ca=the average fruit calcium concentration; Fruit B=the average fruit boron concentration; Fruit K=the average fruit potassium concentration; Fruit Mg=the average fruit magnesium concentration; Fruit P=the average fruit phosphorous concentration; Fruit S=the average fruit sulfur concentration.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 31. Probability of greater F values for preplanned treatment contrast of tomato yield components in Fall 1995 (Experiment 1)

Contrast	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfruwe
Across cultivars:						
T_1 vs T_2[y]	0.2108	0.6280	0.4075	0.3564	0.2974	0.5818
T_1 vs T_3[y]	0.0046	0.0064	0.1607	0.0181	0.8264	0.0036
Across treatments:						
C_1 vs C_2[x]	0.0337	0.1382	0.0001	0.5305	0.0288	0.0002
C_1 vs C_3[x]	0.9451	0.0026	0.0001	0.1401	0.0020	0.0007
For C_1:						
T_1 vs T_2[y]	0.4778	0.5123	0.0846	0.9603	0.8541	0.5097
T_1 vs T_3[y]	0.8875	0.2869	0.0199	0.2780	0.5600	0.2021
For C_2:						
T_1 vs T_2[y]	0.0342	0.4099	0.2939	0.9768	0.7438	0.8915
T_1 vs T_3[y]	0.0020	0.0747	0.9613	0.0356	0.9917	0.0399
For C_3:						
T_1 vs T_2[y]	0.2950	0.8644	0.9977	0.1755	0.2905	0.2303
T_1 vs T_3[y]	0.1220	0.3175	0.0837	0.7528	0.7411	0.0338
At T_1:						
C_1 vs C_2[x]	0.0350	0.9743	0.1053	0.5653	0.1432	0.1063
C_1 vs C_3[x]	0.3674	0.0996	0.0295	0.0070	0.0207	0.2208
At T_2:						
C_1 vs C_2[x]	0.6718	0.2307	0.0300	0.2534	0.1566	0.0013
C_1 vs C_3[x]	0.3871	0.0639	0.0731	0.7789	0.0233	0.0013
At T_3:						
C_1 vs C_2[x]	0.7844	0.1428	0.0020	0.9712	0.3951	0.1952
C_1 vs C_3[x]	0.6458	0.0210	0.0058	0.4513	0.1263	0.1652

[z] Totfruwe=total fruit weight; Totfru#=total fruit number, Avgfruwe=the average fruit weight; Mkfruwe=marketable fruit weight; Mkfru#=marketable fruit number, Avmkfruwe=the average marketable fruit weight.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 32. Probability of greater F values for preplanned treatment contrast of tomato yield components in Spring 1996 (Experiment 2)

Contrast	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfruwe
Across cultivars:						
T_1 vs T_2[y]	0.0558	0.9410	0.0278	0.0018	0.0917	0.0586
T_1 vs T_3[y]	0.0001	0.0006	0.0019	0.0004	0.0484	0.0002
Across treatments:						
C_1 vs C_2[x]	0.0393	0.0960	0.0001	0.3433	0.0001	0.0001
C_1 vs C_3[x]	0.0464	0.0001	0.0001	0.0088	0.0001	0.0001
For C_1:						
T_1 vs T_2[y]	0.6835	0.5995	0.1756	0.0587	0.1550	0.3157
T_1 vs T_3[y]	0.0017	0.0007	0.9915	0.0603	0.1378	0.3211
For C_2:						
T_1 vs T_2[y]	0.0269	0.5021	0.0044	0.0038	0.2558	0.0539
T_1 vs T_3[y]	0.0098	0.0217	0.4936	0.0193	0.2234	0.0865
For C_3:						
T_1 vs T_2[y]	0.6518	0.2931	0.4697	0.8157	0.8135	0.8929
T_1 vs T_3[y]	0.0710	0.9404	0.0012	0.0843	0.5239	0.0006
At T_1:						
C_1 vs C_2[x]	0.6450	0.2846	0.0267	0.4897	0.0039	0.0060
C_1 vs C_3[x]	0.1547	0.0001	0.0001	0.3773	0.0005	0.0001
At T_2:						
C_1 vs C_2[x]	0.0215	0.1631	0.0001	0.5317	0.0095	0.0001
C_1 vs C_3[x]	0.2086	0.0008	0.0018	0.0382	0.0001	0.0002
At T_3:						
C_1 vs C_2[x]	0.5778	0.6373	0.0419	0.0391	0.0001	0.0066
C_1 vs C_3[x]	0.5128	0.0088	0.4902	0.1262	0.0001	0.0091

[z] Totfruwe=total fruit weight; Totfru#=total fruit number; Avgfruwe=the average fruit weight; Mkfruwe=marketable fruit weight; Mkfru#=marketable fruit number; Avmkfruwe=the average marketable fruit weight.
[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.
[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 33. Probability of greater F values for preplanned treatment contrast of tomato yield components in Spring 1996 (Experiment 3)

Contrast	Variables[z]					
	Totfruwe	Totfru#	Avgfruwe	Mkfruwe	Mkfru#	Avmkfruwe
Across cultivars:						
T_1 vs T_2[y]	0.0016	0.8198	0.0016	0.0003	0.0002	0.1294
T_1 vs T_3[y]	0.0047	0.3636	0.0013	0.0001	0.0027	0.0001
Across treatments:						
C_1 vs C_2[x]	0.0127	0.7575	0.0671	0.4021	0.0001	0.0001
C_1 vs C_3[x]	0.0109	0.0064	0.3614	0.0002	0.0001	0.0001
For C_1:						
T_1 vs T_2[y]	0.1827	0.4764	0.9918	0.0525	0.0767	0.7563
T_1 vs T_3[y]	0.0319	0.2686	0.0777	0.0758	0.1212	0.0280
For C_2:						
T_1 vs T_2[y]	0.0086	0.7968	0.0025	0.0324	0.0393	0.5039
T_1 vs T_3[y]	0.1473	0.3990	0.0593	0.0354	0.1147	0.1005
For C_3:						
T_1 vs T_2[y]	0.2937	0.7131	0.0555	0.1215	0.0086	0.0590
T_1 vs T_3[y]	0.1426	0.6316	0.0400	0.0114	0.1025	0.0021
At T_1:						
C_1 vs C_2[x]	0.6344	0.7104	0.6575	0.6319	0.0130	0.0001
C_1 vs C_3[x]	0.1934	0.0657	0.5929	0.0959	0.0004	0.0001
At T_2:						
C_1 vs C_2[x]	0.0140	0.9071	0.0389	0.3999	0.0170	0.0030
C_1 vs C_3[x]	0.1324	0.0099	0.1656	0.0067	0.0021	0.0493
At T_3:						
C_1 vs C_2[x]	0.4236	0.5222	0.3972	0.0517	0.0094	0.0001
C_1 vs C_3[x]	0.1992	0.8230	0.0583	0.0008	0.0018	0.0067

[z] Totfruwe=total fruit weight; Totfru#=total fruit number, Avgfruwe=the average fruit weight; Mkfruwe=marketable fruit weight; Mkfru#=marketable fruit number, Avmkfruwe=the average marketable fruit weight.

[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.

[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 34. Probability of greater F values for preplanned treatment contrast of tomato fruit disorders in Fall 1995 (Experiment 1)

Contrast	Variables[z]		
	BER	Cracking	Catface
Across cultivars:			
T_1 vs T_2[y]	0.0001	0.2906	0.4835
T_1 vs T_3[y]	0.0001	0.0015	0.6215
Across treatments:			
C_1 vs C_2[x]	0.0005	0.0005	0.1142
C_1 vs C_3[x]	0.0213	0.0244	0.5719
For C_1:			
T_1 vs T_2[y]	0.0304	not estimable	0.0599
T_1 vs T_3[y]	0.0304	not estimable	0.2519
For C_2:			
T_1 vs T_2[y]	0.0222	0.7584	0.0396
T_1 vs T_3[y]	0.0687	0.0677	0.2565
For C_3:			
T_1 vs T_2[y]	0.0015	0.1200	0.6486
T_1 vs T_3[y]	0.0021	0.0374	0.6439
At T_1:			
C_1 vs C_2[x]	0.0215	0.0260	0.0113
C_1 vs C_3[x]	0.0429	0.0368	0.0853
At T_2:			
C_1 vs C_2[x]	0.0728	0.0167	0.2275
C_1 vs C_3[x]	0.5421	0.4229	0.3230
At T_3:			
C_1 vs C_2[x]	0.0098	not estimable	0.4452
C_1 vs C_3[x]	0.4919	not estimable	0.9027

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.
[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.
[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 35. Probability of greater F values for preplanned treatment contrast of tomato fruit disorders in Spring 1996 (Experiment 2)

Contrast	Variables[z]		
	BER	Cracking	Catface
Across cultivars:			
T_1 vs T_2[y]	0.0001	0.0001	0.1778
T_1 vs T_3[y]	0.0001	0.0357	0.0621
Across treatments:			
C_1 vs C_2[x]	0.0001	0.0001	0.0007
C_1 vs C_3[x]	0.4417	0.0187	0.7814
For C_1:			
T_1 vs T_2[y]	0.0001	not estimable	0.9437
T_1 vs T_3[y]	0.0001	not estimable	0.4992
For C_2:			
T_1 vs T_2[y]	0.0008	0.0006	0.0894
T_1 vs T_3[y]	0.0117	0.2919	0.2690
For C_3:			
T_1 vs T_2[y]	0.0331	0.0633	0.6950
T_1 vs T_3[y]	0.0013	0.0440	0.2747
At T_1:			
C_1 vs C_2[x]	0.0537	not estimable	0.5304
C_1 vs C_3[x]	0.8630	not estimable	0.4647
At T_2:			
C_1 vs C_2[x]	0.1136	0.0012	0.0039
C_1 vs C_3[x]	0.1664	0.1723	0.6107
At T_3:			
C_1 vs C_2[x]	0.0022	0.1250	0.1388
C_1 vs C_3[x]	0.5707	0.0245	0.9053

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.
[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.
[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Table 36. Probability of greater F values for preplanned treatment contrast of tomato fruit disorders in Spring 1996 (Experiment 3)

Contrast	Variables[z]		
	BER	Cracking	Catface
Across cultivars:			
T_1 vs T_2[y]	0.0001	0.0094	0.3194
T_1 vs T_3[y]	0.0296	0.0431	0.0116
Across treatments:			
C_1 vs C_2[x]	0.0001	0.0123	0.0440
C_1 vs C_3[x]	0.0148	0.3066	0.2981
For C_1:			
T_1 vs T_2[y]	0.0124	0.4987	0.2468
T_1 vs T_3[y]	0.0059	0.7307	0.6036
For C_2:			
T_1 vs T_2[y]	0.0037	0.0266	0.0338
T_1 vs T_3[y]	0.9920	0.0244	0.0538
For C_3:			
T_1 vs T_2[y]	0.0083	0.0584	0.8471
T_1 vs T_3[y]	0.5714	0.5543	0.1388
At T_1:			
C_1 vs C_2[x]	0.0398	0.8007	0.0205
C_1 vs C_3[x]	0.1414	0.1931	0.2207
At T_2:			
C_1 vs C_2[x]	0.1502	0.0930	0.6857
C_1 vs C_3[x]	0.6105	0.9305	0.6210
At T_3:			
C_1 vs C_2[x]	0.0011	0.0150	0.1116
C_1 vs C_3[x]	0.0087	0.5227	0.9370

[z] BER=incidence of blossom-end rot; Cracking=incidence of cracking; Catface=incidence of catface.
[y] T_1=low calcium treatment; T_2=medium calcium treatment; T_3=high calcium treatment.
[x] C_1=cultivar 'Mountain Supreme'; C_2=cultivar 'Celebrity'; C_3=cultivar 'Sunrise'.

Appendix E

Nutrients in solutions over time

Table 37. Boron concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	1.13	1.05	1.11	1.15	9.66	8.73
10/27/95	1.15	0.99	1.10	1.14	10.32	9.95
11/3/95	1.41	1.17	1.73	1.12	10.36	9.50
11/10/95	1.65	1.49	1.60	1.62	10.76	10.99
11/17/95	1.96	1.93	2.09	2.01	12.05	12.01
11/24/95	2.07	2.14	2.02	1.90	13.93	12.49
12/1/95	1.71	2.16	1.73	1.94	10.70	11.28
12/8/95	1.27	1.44	1.78	2.17	9.68	10.32
12/15/95	1.18	1.26	2.81	3.12	11.05	10.76
12/22/95	2.70	3.09	2.91	3.29	9.78	10.09
1/4/96	3.32	4.38	4.55	5.00	9.59	11.01
1/12/96	1.16	3.13	1.18	3.17	8.36	9.86
1/19/96	1.49	2.08	1.69	2.42	6.55	9.61
1/26/96	1.39	1.49	1.51	1.79	3.68	2.91
2/9/96	2.09	1.35	2.35	1.44	1.22	0.94
2/16/96	2.51	1.54	2.47	1.52	1.32	1.05
3/1/96	2.55	1.84	2.69	1.76	1.18	1.09
3/7/96	4.37	2.03	4.60	2.07	1.49	1.21

Table 38. Calcium concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	17.85	16.22	209.46	193.89	900.18	951.53
10/27/95	23.23	17.35	201.95	198.34	978.46	989.53
11/3/95	20.77	14.14	209.94	197.50	969.15	1011.28
11/10/95	19.85	14.92	207.99	194.58	1011.38	1054.44
11/17/95	16.95	13.68	207.74	202.14	981.60	1057.58
11/24/95	20.15	13.43	213.13	216.68	967.33	1129.45
12/1/95	20.22	16.82	208.71	216.28	1010.37	1126.02
12/8/95	17.71	15.09	200.45	399.99	1020.01	1190.57
12/15/95	24.98	18.58	184.91	253.21	997.18	1179.80
12/22/95	27.27	23.45	190.60	247.60	956.40	1144.17
1/4/96	26.03	25.87	192.34	247.57	1009.99	1175.56
1/12/96	28.88	23.36	30.50	124.87	1031.23	1282.18
1/19/96	28.33	20.32	154.09	96.91	997.44	1320.71
1/26/96	27.64	17.84	108.27	122.40	1010.99	1362.71
2/9/96	23.44	14.90	136.06	109.94	988.11	1363.27
2/16/96	24.30	11.73	104.98	151.28	959.10	1357.30
3/1/96	22.71	11.28	204.86	241.00	997.94	1695.60
3/7/96	22.35	13.86	205.72	305.75	982.29	1815.91

Table 39. Potassium concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	56.69	45.80	63.23	52.72	76.95	73.49
10/27/95	65.11	48.82	68.06	50.50	98.70	78.10
11/3/95	120.63	55.57	126.68	58.51	158.68	85.26
11/10/95	140.70	102.10	131.01	103.38	133.99	121.61
11/17/95	183.86	153.47	192.78	157.44	192.97	167.25
11/24/95	180.42	153.84	172.90	165.87	194.50	183.12
12/1/95	169.49	180.34	157.01	163.15	172.44	188.20
12/8/95	168.10	154.37	148.55	152.16	190.61	179.32
12/15/95	168.48	151.93	163.71	155.16	192.06	186.24
12/22/95	163.02	159.05	167.94	159.09	208.08	186.97
1/4/96	165.36	164.29	175.91	172.28	204.44	205.53
1/12/96	12.08	68.59	13.36	68.05	30.95	61.35
1/19/96	27.85	22.18	30.23	19.69	48.43	25.67
1/26/96	22.74	9.11	24.34	7.57	41.93	14.40
2/9/96	68.58	9.54	65.43	6.64	82.72	27.78
2/16/96	79.75	13.82	79.44	12.90	95.92	38.21
3/1/96	84.71	25.69	85.37	40.20	103.44	69.06
3/7/96	158.38	25.31	162.28	35.54	179.40	70.29

Table 40. Magnesium concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	11.58	11.08	11.54	11.42	10.88	11.73
10/27/95	13.32	11.26	12.96	11.59	14.03	12.52
11/3/95	20.37	10.33	19.94	11.77	20.46	12.79
11/10/95	19.88	15.63	19.15	17.75	19.46	19.27
11/17/95	26.69	19.90	25.92	23.17	25.67	24.42
11/24/95	28.76	20.71	26.83	26.96	28.15	29.72
12/1/95	27.14	26.50	25.54	28.62	27.10	30.67
12/8/95	27.26	25.83	24.45	31.34	28.39	32.84
12/15/95	29.99	27.32	29.43	32.93	30.41	34.00
12/22/95	30.55	31.83	29.53	35.04	31.54	34.97
1/4/96	31.13	34.79	30.70	36.09	31.51	36.92
1/12/96	8.12	20.89	8.47	22.77	7.95	19.14
1/19/96	10.34	13.63	10.34	18.76	9.91	14.89
1/26/96	9.35	10.09	9.36	15.00	8.97	12.81
2/9/96	14.28	9.44	13.71	12.39	13.90	15.05
2/16/96	17.19	8.43	16.62	13.24	16.02	15.50
3/1/96	17.34	6.64	16.64	13.92	16.91	20.74
3/7/96	26.11	6.84	25.40	16.73	25.63	21.56

Table 41. Phosphorous concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	13.36	13.01	11.58	4.25	6.52	2.57
10/27/95	15.05	12.70	8.70	4.19	7.38	2.25
11/3/95	28.83	13.71	26.43	5.52	20.07	3.58
11/10/95	24.34	24.40	27.35	14.14	22.64	11.78
11/17/95	42.87	35.94	42.49	26.93	32.00	24.31
11/24/95	42.31	37.00	40.54	29.59	27.17	27.80
12/1/95	35.55	39.23	33.95	31.35	35.89	30.38
12/8/95	37.74	37.45	34.20	29.41	39.61	30.00
12/15/95	36.95	37.36	21.99	31.88	23.64	29.12
12/22/95	39.49	41.12	24.23	32.64	16.81	27.98
1/4/96	39.75	41.68	24.87	29.38	34.49	25.40
1/12/96	2.49	20.77	2.94	13.44	1.98	6.86
1/19/96	6.62	8.63	5.70	6.71	0.23	2.47
1/26/96	5.44	3.98	5.33	2.40	0.98	1.45
2/9/96	14.75	4.14	7.02	1.79	10.74	2.15
2/16/96	18.42	4.03	10.63	0.71	1.12	0.49
3/1/96	19.99	3.53	4.84	0.47	15.44	0.74
3/7/96	38.46	5.40	24.52	2.01	35.74	0.96

Table 42. Sulfur concentration in the solutions in Fall 1995 (Experiment 1)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
10/20/95	17.17	17.30	17.26	17.69	16.57	18.14
10/27/95	18.13	16.98	18.31	17.55	19.04	18.01
11/3/95	27.92	17.59	28.02	17.71	27.84	17.77
11/10/95	30.26	27.38	29.50	27.07	29.18	26.50
11/17/95	35.93	34.50	35.83	34.37	35.33	34.11
11/24/95	38.51	38.67	37.50	38.46	39.44	40.76
12/1/95	37.54	38.74	36.46	38.15	39.10	41.08
12/8/95	36.46	38.09	33.22	37.95	38.07	40.80
12/15/95	36.45	37.12	37.83	39.50	38.97	40.44
12/22/95	38.97	39.71	39.01	40.92	40.90	42.03
1/4/96	44.75	45.65	46.07	45.20	46.01	44.57
1/12/96	14.70	31.27	15.81	29.51	14.23	22.70
1/19/96	17.91	20.22	18.55	21.89	16.49	13.76
1/26/96	19.21	16.53	19.72	17.22	18.25	13.07
2/9/96	21.27	18.01	21.31	17.45	24.26	20.86
2/16/96	24.25	21.79	24.36	22.33	26.34	21.33
3/1/96	24.14	25.52	23.49	25.21	27.20	30.10
3/7/96	34.04	31.01	34.40	30.67	38.81	33.39

Table 43. Nutrient concentration in solutions in Spring 1996 (Experiment 2)

Date	Low calcium treatment						Medium calcium treatment						High calcium treatment					
	B	Ca	K	Mg	P	S	B	Ca	K	Mg	P	S	B	Ca	K	Mg	P	S
	ppm																	
1/26/96	0	31	32	11	6	20	0	67	33	11	6	19	2	1287	51	13	2	23
2/9/96	0	26	82	17	16	25	0	139	85	16	1	23	2	1150	93	17	11	24
2/16/96	0	25	103	19	18	27	0	113	106	20	3	25	3	1290	121	22	3	33
3/1/96	0	25	114	20	22	29	0	254	119	21	4	26	2	1214	114	21	16	28
3/8/96	1	25	226	30	42	41	1	264	238	33	24	38	3	1143	210	32	33	42
3/15/96	1	27	219	32	39	42	1	268	226	35	20	39	3	3216	269	35	22	42
3/25/96	1	27	210	31	39	41	1	244	226	35	22	39	3	2358	265	37	26	46
3/29/96	1	22	193	30	37	40	1	243	205	32	23	37	3	1696	226	35	32	45
4/5/96	1	27	214	31	41	41	1	205	208	33	22	37	3	1126	225	34	37	43
4/12/96	1	29	209	32	41	40	1	215	225	35	21	37	3	1205	234	36	30	45
4/19/96	1	30	208	33	42	41	1	203	211	34	18	37	3	1220	229	36	28	44
4/26/96	1	26	204	32	41	42	1	207	216	34	21	39	3	1242	240	36	30	47
5/3/96	1	29	255	38	48	49	1	202	236	37	26	41	2	1098	282	43	37	47
5/10/96	1	25	355	51	71	67	1	206	329	48	44	57	2	1402	371	52	61	64
5/17/96	1	17	278	38	55	50	1	190	330	47	50	55	2	415	367	54	74	68
5/24/96	1	26	485	67	92	88	1	237	447	70	69	82	2	1020	446	64	82	77
6/7/96	1	31	367	68	84	73	1	176	383	71	72	74	2	1305	449	67	68	97
6/21/96	1	28	363	67	87	72	1	214	360	66	82	70	2	1138	388	51	76	79
6/28/96	1	29	180	36	43	39	1	35	182	36	44	40	1	459	202	20	46	46

Table 44. Boron concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	.... ppm					
3/25/96	0.57	0.49	0.58	0.46	7.36	8.17
3/29/96	0.49	0.58	0.58	0.50	6.88	6.90
4/5/96	0.53	0.58	0.52	0.51	8.57	7.55
4/12/96	0.55	0.56	0.57	0.56	8.44	7.16
4/19/96	0.55	0.57	0.55	0.60	8.22	7.68
4/26/96	0.53	0.57	0.59	0.62	7.15	7.50
5/3/96	0.75	0.66	0.87	0.79	8.33	7.07
5/10/96	1.01	0.97	0.75	1.10	8.13	7.37
5/17/96	1.35	1.44	1.36	1.60	7.38	7.56
5/24/96	1.43	1.56	1.47	1.67	8.27	8.55
6/7/96	1.43	1.71	1.46	1.84	6.70	8.25
6/21/96	1.46	1.73	1.44	1.90	7.64	9.26
6/28/96	0.97	1.63	1.00	1.78	6.81	8.39

Table 45. Calcium concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
3/25/96	27.69	27.67	233.62	176.81	3774.64	968.59
3/29/96	22.29	28.80	215.55	182.78	2013.57	1467.29
4/5/96	22.47	28.62	200.16	209.08	966.32	1154.97
4/12/96	30.46	28.20	210.97	214.37	999.16	983.08
4/19/96	30.10	27.06	198.91	213.01	1167.01	1156.55
4/26/96	26.97	20.39	205.58	227.65	1007.56	1260.78
5/3/96	28.77	16.81	217.97	256.07	3548.77	1299.97
5/10/96	23.50	16.35	148.80	283.93	1781.25	1517.08
5/17/96	20.63	16.86	200.83	257.19	574.76	1688.33
5/24/96	21.17	18.39	213.67	293.10	900.09	2356.19
6/7/96	30.52	28.98	170.31	296.95	1059.67	1916.38
6/21/96	27.32	32.51	212.22	324.35	1151.87	2357.30
6/28/96	29.64	36.66	39.82	295.22	561.88	1817.53

Table 46. Potassium concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
3/25/96	185.35	103.37	207.75	123.66	258.64	146.25
3/29/96	179.84	152.67	182.78	143.65	197.02	201.99
4/5/96	163.99	160.24	203.13	170.36	188.74	174.39
4/12/96	211.77	183.05	219.51	188.45	195.36	174.39
4/19/96	203.49	176.91	206.62	184.77	200.88	171.08
4/26/96	205.08	160.60	219.21	169.15	196.47	163.36
5/3/96	258.50	126.82	273.76	173.26	279.25	132.45
5/10/96	332.17	231.07	235.71	262.20	321.19	229.58
5/17/96	326.91	251.46	320.82	274.00	324.50	274.28
5/24/96	356.04	305.99	372.29	360.54	381.90	402.87
6/7/96	374.17	392.96	386.05	438.49	400.66	471.85
6/21/96	365.94	436.08	369.72	512.06	363.13	560.15
6/28/96	176.29	410.09	178.73	479.09	201.43	532.56

Table 47. Magnesium concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
3/25/96	29.58	24.11	32.90	27.29	18.54	19.89
3/29/96	29.09	30.26	29.82	28.04	18.09	24.14
4/5/96	26.30	30.16	31.22	32.24	21.42	21.93
4/12/96	32.04	30.87	33.71	32.22	25.86	21.15
4/19/96	31.65	29.01	32.93	32.34	23.01	24.62
4/26/96	31.71	22.83	34.32	31.91	21.33	23.96
5/3/96	39.04	18.66	42.22	35.09	35.79	21.88
5/10/96	49.23	33.38	34.10	51.58	45.84	40.45
5/17/96	48.32	38.43	47.67	53.74	42.42	54.47
5/24/96	53.92	49.99	56.02	67.23	53.79	92.51
6/7/96	60.95	74.15	71.08	97.25	54.37	92.37
6/21/96	66.18	85.85	66.23	109.83	48.15	110.02
6/28/96	35.50	81.13	35.45	100.90	24.98	91.16

Table 48. Phosphorous concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
3/25/96	40.35	31.00	21.56	14.37	15.78	10.92
3/29/96	38.84	38.98	23.81	17.70	18.64	18.47
4/5/96	35.93	39.33	24.00	20.43	18.20	15.53
4/12/96	42.33	41.42	20.50	23.70	18.76	16.63
4/19/96	40.63	41.00	18.05	23.71	29.02	16.54
4/26/96	40.94	39.02	22.01	22.96	23.30	13.91
5/3/96	48.79	32.07	27.47	21.09	28.30	8.31
5/10/96	68.09	59.80	38.13	48.54	49.50	27.63
5/17/96	72.36	73.23	68.10	67.52	59.39	51.52
5/24/96	81.67	78.70	77.85	80.97	70.70	96.49
6/7/96	85.23	96.09	75.06	95.05	54.71	90.65
6/21/96	85.20	103.40	82.81	108.87	67.31	108.57
6/28/96	42.38	102.38	44.35	106.13	41.32	91.69

Table 49. Sulfur concentration in the solutions in Spring 1996 (Experiment 3)

Date	Low Ca treatment		Medium Ca treatment		High Ca treatment	
	in	out	in	out	in	out
	ppm					
3/25/96	38.82	34.84	49.97	43.19	42.57	40.94
3/29/96	48.87	44.69	37.99	34.84	37.18	42.56
4/5/96	33.93	38.81	37.37	40.00	41.56	40.41
4/12/96	40.74	40.27	38.28	39.78	47.14	40.18
4/19/96	40.08	39.62	37.82	42.15	43.04	46.06
4/26/96	42.40	41.38	41.00	43.71	43.17	44.26
5/3/96	50.88	38.44	48.25	44.04	64.98	41.17
5/10/96	67.18	62.26	43.29	68.00	82.96	65.86
5/17/96	65.27	67.43	64.05	72.50	72.52	82.62
5/24/96	72.55	77.15	77.76	92.22	88.39	137.44
6/7/96	78.62	97.14	74.38	99.36	84.13	129.69
6/21/96	71.05	98.90	70.86	111.24	78.97	158.33
6/28/96	39.15	95.77	40.60	104.75	47.46	130.00

Appendix F

Temperature and relative humidity

Table 50. The average of daily temperature and relative humidity (Experiment 1)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
9/26/95	33.0	20.5	79.0	42.0
9/27/95	36.5	18.5	75.0	29.0
9/28/95	37.5	17.0	75.5	27.5
9/29/95	33.5	17.5	78.0	34.0
9/30/95	.	.	.	.
10/1/95	.	.	.	.
10/2/95	39.5	19.0	82.5	28.0
10/3/95	37.5	21.0	86.5	30.0
10/4/95	24.0	21.0	89.0	82.5
10/5/95	24.0	20.0	94.5	77.0
10/6/95	26.5	21.0	90.5	65.5
10/7/95	37.5	16.0	76.5	31.0
10/8/95	34.5	14.0	73.0	28.5
10/9/95	34.5	14.0	74.0	24.0
10/10/95	35.5	16.0	78.5	27.5
10/11/95	35.5	17.0	79.0	30.5
10/12/95	37.0	17.0	77.5	27.5
10/13/95	37.0	20.0	74.5	27.0
10/14/95	.	.	.	.
10/15/95	27.5	12.0	85.0	29.0
10/16/95	31.5	12.5	68.0	28.5
10/17/95	34.0	19.0	50.5	22.0
10/18/95	.	.	.	.
10/19/95	33.5	19.0	62.0	22.5
10/20/95	35.0	19.5	68.5	28.5
10/21/95	.	.	.	.
10/22/95	36.5	19.0	75.5	23.5
10/23/95	41.5	19.5	65.0	18.0
10/24/95	34.5	19.5	65.5	23.5
10/25/95	31.5	19.0	75.5	32.5
10/26/95	33.0	18.0	62.5	22.0
10/27/95	32.5	19.0	72.5	26.0
10/28/95	29.5	19.0	80.5	26.0
10/29/95	29.5	19.0	49.5	24.5
10/30/95	29.5	19.0	49.5	22.5
10/31/95	26.5	19.5	75.0	29.0
11/1/95	23.0	19.5	73.0	60.0
11/2/95	29.0	19.5	85.5	48.0
11/3/95	26.5	19.0	87.5	66.0
11/4/95	.	.	.	.
11/5/95	39.0	18.0	74.0	23.0

Table 50. (Continued)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
11/6/95	30.5	19.0	72.5	37.5
11/7/95	29.5	19.0	78.5	30.5
11/8/95	26.0	18.5	85.0	60.0
11/9/95	32.5	17.5	67.0	28.0
11/10/95	36.0	19.0	61.5	19.0
11/11/95	33.5	17.0	81.0	25.0
11/12/95	34.5	15.5	58.5	21.0
11/13/95	28.5	19.0	64.0	23.0
11/14/95	36.0	18.5	68.0	20.5
11/15/95	21.5	16.5	69.0	44.5
11/16/95	32.0	15.5	58.5	23.0
11/17/95	29.0	17.0	63.0	35.0
11/18/95	35.0	18.5	66.0	24.5
11/19/95	31.5	19.0	70.5	32.0
11/20/95	37.0	18.5	65.5	23.5
11/21/95	37.0	19.0	68.5	27.0
11/22/95	36.0	17.0	65.5	21.5
11/23/95	33.0	18.5	67.0	25.0
11/24/95	20.0	18.5	74.0	64.0
11/25/95	30.5	18.5	76.0	33.5
11/26/95	35.0	17.5	67.0	25.0
11/27/95	35.5	18.5	71.5	25.0
11/28/95	20.5	18.5	78.5	66.5
11/29/95	21.0	18.0	79.5	64.5
11/30/95	21.0	18.0	76.0	58.5
12/1/95	30.5	16.0	70.5	24.0
12/2/95	35.0	18.5	71.5	24.0
12/3/95	34.5	18.5	74.5	30.0
12/4/95	28.0	19.0	80.5	35.5
12/5/95	31.5	18.5	78.5	22.5
12/6/95	21.5	18.5	81.0	61.0
12/7/95	29.5	16.0	71.0	31.5
12/8/95	30.0	15.5	67.0	30.5
12/9/95	25.5	17.5	73.0	51.5
12/10/95	23.0	9.0	69.5	38.5
12/11/95	.	.	.	.
12/12/95	31.5	12.0	65.0	35.0
12/13/95	20.0	17.0	75.0	58.0
12/14/95	31.0	19.5	76.5	35.5
12/15/95	27.5	20.0	82.5	62.5
12/16/95	30.0	20.0	82.5	47.0

Table 50. (Continued)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
12/17/95	34.5	19.0	79.0	33.5
12/18/95	23.5	20.0	82.0	65.0
12/19/95	21.0	19.0	83.5	72.0
12/20/95	31.0	14.0	83.0	54.5
12/21/95	31.0	13.5	67.5	29.0
12/22/95	25.5	12.0	69.5	39.0
12/23/95	17.5	8.0	54.5	42.0
12/24/95	24.5	12.0	63.0	34.0
12/25/95	24.5	13.5	65.0	42.0
12/26/95	19.0	12.0	65.0	46.5
12/27/95	27.5	14.0	68.5	32.0
12/28/95	21.0	12.5	67.5	45.0
12/29/95	27.0	11.5	63.0	33.0
12/30/95	28.5	13.0	63.5	33.5
12/31/95	30.0	18.0	69.0	33.0
1/1/96	21.0	18.0	73.5	55.0
1/2/96	21.0	18.0	77.0	60.0
1/3/96	21.0	16.5	79.5	58.0
1/4/96	20.5	15.0	68.5	49.5
1/5/96	.	.	.	.
1/6/96	25.5	16.0	73.5	39.0
1/7/96	.	.	.	.
1/8/96	.	.	.	.
1/9/96	28.5	11.0	62.0	36.0
1/10/96	28.5	16.0	63.5	33.5
1/11/96	32.5	15.5	65.5	31.5
1/12/96	22.0	12.0	72.5	54.5
1/13/96	22.5	15.0	69.5	57.5
1/14/96	33.5	16.0	69.5	34.0
1/15/96	23.5	17.0	72.0	58.5
1/16/96	33.5	19.0	71.0	29.0
1/17/96	29.0	22.0	79.0	47.0
1/18/96	30.0	22.0	79.5	41.5
1/19/96	32.0	13.0	79.0	40.0
1/20/96	23.0	10.0	62.5	47.0
1/21/96	30.5	16.5	67.0	31.5
1/22/96	27.5	14.5	69.0	46.5
1/23/96	30.5	17.0	66.0	32.5
1/24/96	29.0	21.0	75.0	35.5
1/25/96	25.5	13.5	76.0	41.0

Table 50. (Continued)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
1/26/96	32.0	15.5	65.0	25.5
1/27/96	25.5	16.0	74.5	33.5
1/28/96	31.0	13.5	59.0	26.0
1/29/96	32.5	17.5	63.0	24.0
1/30/96	23.0	19.0	70.0	56.5
1/31/96	23.0	15.0	72.0	60.0
2/1/96	23.0	14.5	65.5	54.0
2/2/96	.	.	.	.
2/3/96	23.0	10.0	69.0	46.0
2/4/96	.	.	.	.
2/5/96	30.0	6.0	60.5	28.0
2/6/96	27.0	9.5	58.0	35.0
2/7/96	25.0	16.0	64.0	41.5
2/8/96	24.5	17.0	73.0	54.5
2/9/96	25.0	19.0	76.0	49.0
2/10/96	.	.	.	.
2/11/96	36.0	17.5	76.5	27.5
2/12/96	33.5	16.0	62.0	28.0
2/13/96	28.5	15.0	62.0	37.0
2/14/96	31.5	18.5	67.0	31.0
2/15/96	25.0	20.0	71.5	41.0
2/16/96	36.5	15.5	62.0	26.0
2/17/96	29.0	12.0	60.0	34.0
2/18/96	.	.	.	.
2/19/96	36.0	15.5	58.0	20.0
2/20/96	33.5	20.5	76.0	26.0
2/21/96	26.0	21.5	78.0	60.0
2/22/96	34.5	22.5	80.0	41.5
2/23/96	30.0	22.5	77.5	48.5
2/24/96	37.5	18.5	61.5	16.0
2/25/96	.	.	.	.
2/26/96	44.5	20.5	69.0	16.0
2/27/96	39.0	22.5	78.5	29.5
2/28/96	33.0	22.5	80.0	41.5
2/29/96	40.5	16.5	70.0	20.0
2/30/96	.	.	.	.
3/1/96	37.0	17.5	60.0	21.0
3/2/96	31.5	15.0	59.0	19.0
3/3/96	25.5	15.5	49.0	27.5
3/4/96	38.0	17.0	54.0	17.0
3/5/96	40.0	22.0	75.5	17.0
3/6/96	23.5	21.5	76.0	68.5
3/7/96	41.0	20.0	76.0	27.5

Table 51. The average of daily temperature and relative humidity (Experiment 2 & 3)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
4/29/96	30.0	20.5	75.5	43.0
4/30/96	36.0	15.0	86.0	36.0
5/1/96	29.0	9.0	79.5	35.0
5/2/96	36.0	16.0	78.0	28.0
5/3/96	33.0	14.0	85.0	32.5
5/4/96	35.0	17.0	86.0	36.5
5/5/96	33.5	19.0	81.5	44.0
5/6/96	35.0	19.0	92.0	46.5
5/7/96	30.0	17.5	93.5	59.5
5/8/96	28.5	18.0	94.0	65.5
5/9/96	35.0	17.0	92.5	43.0
5/10/96	36.0	18.0	91.0	39.5
5/11/96	36.0	18.5	91.0	45.0
5/12/96	32.0	13.0	85.5	31.5
5/13/96	33.0	14.0	82.0	30.0
5/14/96	27.0	10.0	84.0	53.0
5/15/96	31.0	15.5	91.5	33.5
5/16/96	30.0	17.0	91.5	53.5
5/17/96	34.0	17.0	93.0	51.5
5/18/96	36.0	20.0	93.0	48.0
5/19/96	37.5	19.5	91.0	47.5
5/20/96	38.0	20.0	92.5	44.5
5/21/96	37.0	21.0	88.5	41.0
5/22/96	38.5	19.0	88.0	42.5
5/23/96	35.0	15.0	86.5	40.0
5/24/96	37.0	21.0	91.0	41.0
5/25/96	39.0	21.0	92.0	48.5
5/26/96	37.5	21.0	91.0	50.0
5/27/96	32.0	20.0	93.5	62.5
5/28/96	36.0	20.0	93.0	50.5
5/29/96	34.0	22.0	92.0	50.5
5/30/96	31.0	19.0	92.0	57.5
5/31/96	32.5	16.0	89.5	44.5

Table 51. (Continued)

Date	Temperature		Relative humidity	
	Minimum (°C)	Maximum (°C)	Minimum (%)	Maximum (%)
6/1/96	.	.	.	.
6/2/96	33.5	16.0	87.5	40.5
6/3/96	28.5	18.0	92.0	57.0
6/4/96	34.0	16.0	90.0	44.5
6/5/96	33.0	16.0	90.5	42.5
6/6/96	35.5	16.5	90.5	38.5
6/7/96	35.5	18.5	90.5	44.5
6/8/96	36.5	19.0	92.5	42.5
6/9/96	24.5	18.5	94.0	81.0
6/10/96	29.5	17.0	92.5	63.5
6/11/96	32.0	17.0	94.5	49.5
6/12/96	31.0	19.0	94.0	62.5
6/13/96	32.5	18.5	94.0	58.0
6/14/96	35.5	19.0	94.0	50.5
6/15/96	37.0	19.0	93.0	48.0
6/16/96	37.5	20.0	93.5	45.0
6/17/96	38.5	21.0	93.0	43.5
6/18/96	38.5	22.0	92.0	46.0
6/19/96	39.0	22.0	92.5	44.0
6/20/96	.	.	.	.
6/21/96	38.5	21.0	93.5	47.5
6/22/96	39.5	21.0	92.5	43.0
6/23/96	39.5	22.0	93.0	44.0
6/24/96	40.5	22.0	93.0	47.0
6/25/96	39.0	21.5	94.5	51.0
6/26/96	37.0	20.0	90.0	50.0
6/27/96	37.0	20.0	90.5	41.5
6/28/96	38.0	20.0	91.5	43.0
6/29/96	38.0	20.5	92.0	37.5
6/30/96	38.5	22.0	92.5	43.5
7/1/96	37.5	22.5	93.0	47.5
7/2/96	39.5	23.0	93.5	48.0
7/3/96	38.0	21.0	92.5	44.0

Table 52. The monthly temperature and relative humidity in greenhouse during tomato experiment (Experiment 1)

Month/Year	Temperature (°C)[z]		Relative Humidity (%)[z]	
	Maximum	Minimum	Maximum	Minimum
September 1995[y]	35.1 ± 2.2	18.4 ± 1.5	76.9 ± 1.9	33.1 ± 6.5
October 1995	32.9 ± 4.6	18.1 ± 2.5	73.4 ± 11.8	31.7 ± 16.1
November 1995	30.3 ± 5.7	18.1 ± 1.1	71.4 ± 7.8	36.4 ± 16.6
December 1995	27.2 ± 4.8	15.6 ± 3.5	72.1 ± 7.5	40.7 ± 13.0
January 1996	27.1 ± 4.4	16.1 ± 2.9	70.5 ± 5.8	42.3 ± 11.7
February 1996	31.3 ± 6.0	17.1 ± 4.4	69.0 ± 7.5	35.5 ± 12.4
March 1996[x]	33.8 ± 7.1	18.4 ± 2.8	64.2 ± 11.4	28.2 ± 18.3

[z] The data shown is mean ± standard deviation.
[y] The data came from the fourth week only.
[x] The data came from the first week only.

Table 53. The monthly temperature and relative humidity in greenhouse during tomato experiment (Experiment 2 & 3)

Month/Year	Temperature (°C)[z]		Relative Humidity (%)[z]	
	Maximum	Minimum	Maximum	Minimum
April 1996[y]	33.0 ± 4.2	17.8 ± 3.9	80.8 ± 7.4	39.5 ± 4.9
May 1996	34.0 ± 3.1	17.5 ± 3.2	89.2 ± 4.4	45.0 ± 9.4
June 1996	35.6 ± 3.9	19.4 ± 2.0	92.3 ± 1.7	48.2 ± 9.2
July 1996[x]	38.3 ± 1.0	22.2 ± 1.0	93.0 ± 0.5	46.5 ± 2.2

[z] The data shown is mean ± standard deviation.
[y] The data came from the fourth week only.
[x] The data came from the first week only.

VITA

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