STUDIES ON THE EFFECTS OF GENOTYPE AND RELATIVELY COOL TEMPERATURES ON ROUGH FRUIT PRODUCTION BY TOMATO (*Lycopersicon esculentum*, Mill.)

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

in

THE DEPARTMENT OF
PLANT SCIENCE

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

May, 1977

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ABSTRACT

Tomato fruits which are misshapen or rough are frequently a problem in the field crop, and sometimes in the greenhouse crop. This horticultural problem has been attributed to the exposure of seedling plants to relatively cool temperatures (below $15^{o}C$), but lack of knowledge about conditions causing rough fruit resulted in experiments to explore the influence of genotype and relatively cool temperatures on the production of rough fruit.

A field study was carried out at the University of British Columbia in 1975 using 3 cultivars (Bonny Best, Fireball and Immur Prior Beta [IPB]) and 2 reciprocal hybrids of Bonny Best and IPB. In that season, there was a substantial quantity of rough fruit, and there were highly significant differences among genotypes.

Controlled environment studies were used in 3 greenhouse experiments. In the first, tomato seedlings of 6 cultivars (Bonny Best, Cold Set, Early Red Chief, Fireball, IPB and Vendor) were chilled for either 3 or 7 nights to $10^{o} \pm 1^{o}C$ at each of 4 different ages ranging from 3.5 to 6.5 weeks after seeding. Control plants were kept at $19^{o} \pm 1^{o}C$. None of the cultivars in any treatment produced enough rough fruit to be of any horticultural concern, but there were some highly significant differences (1% level) among the cultivars for the number of rough fruits produced.

The second experiment employed more severe chilling conditions. Seedlings from 4 age groups ranging from 3 to 6 weeks were chilled for

2 weeks using a night temperature low of 4.4 °C and a day high of 12.8 °C. Four cultivars (Cold Set, Fireball, IPB and Vendor) were used, and although there were significant differences (5% level), the numbers of rough fruit did not match the horticultural problem.

The third controlled environment experiment employed a regime of hourly changes in temperature to range from a night low of 4.4 °C and a day high of 21.1 °C, using only 2 cultivars (IPB and Vendor). Control plants were kept at 20.0°C/23.9°C. The plants were transferred to controlled environment chambers 35 days after seeding, and kept in the contrasting temperature regimes until fruit matured. Although the IPB had a significantly greater number of rough fruit than Vendor, the magnitude of the numbers of rough fruit were too small to be of practical importance. Apparently, the rough fruit problem is not caused by the simple matter of exposure to chilling temperatures, and it is supposed that an interaction, possibly a very complex one, may be the cause of this type of misshapen fruit.

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ACKNOWLEDGEMENT

The writer wishes to express her thanks to her supervisor of studies, Dr. C.A. Hornby, Associate Professor,Horticulture and Plant Breeding, for his encouraging interest and invaluable assistance in the preparation of the thesis.

Acknowledgement is given to the other members of the Committee; Dr. V.C. Runeckles, Professor and Chairman of the Department of Plant Science, Dr. R.J. Copeman, Assistant Professor, Department of Plant Science and Dr. C.W. Roberts, Professor of Poultry Genetics for reviewing the manuscript. Special thanks are expressed to Dr. G.W. Eaton, Professor, Department of Plant Science, for helping with the statistical analysis of the data.

The writer is indebted to the Canadian International Development Agency and the University of Science and Technology, Kumasi, Ghana for financial assistance. Finally she wishes to express her gratitude to Mr. Ilmars Derics, Ms. Diane Green and all the other members of the Department of Plant Science, who helped in various ways in the preparation of the thesis.

INTRODUCTION

Malformation of tomato fruit is a problem which has caused growers a loss of marketable product and/or revenue for many years. A badly misshapen fruit is a problem whether it is to be used for processing or for the fresh market. Gould (12) stated that one of the qualities for a good processing tomato cultivar is the ability to produce smooth fruit because an irregular outline increases the difficulty in peeling, and results in a very high percentage of waste. Invariably the exhibition standards of perfection or grade descriptions for the fresh market fruit, emphasize smooth, regular shaped fruit. Rough or deformed fruits will thus have to be discarded during the grading process. However, if the malformation is not too serious, but if there is a relatively high proportion of deformed fruit, the crop will be given a lower grade resulting in reduced revenue to the grower.

Fruit malformation, other than "catfacing" (Knavel and Mohr, 21) is often prominent in the field crop, especially when plants are started early in the season to obtain an adequate yield in a short growing season. The tomato is a warm season crop and reports of the optimum growing temperatures for the production of a high percentage of No. 1 fruit have been given by Abdalla and Verkerk (1), Shoemaker (35), Snyder (36), Stoner (37), Verkerk (44) and others. The temperatures range between a nighttime low of 17°C and a daytime high of 24°C. During the propagation period and for some weeks after transplanting to the field, when the flower buds are being differentiated, temperatures may be cooler than the recommended

optimum range. Thus, there is a common belief that exposure of the plants to relatively cool temperatures results in misshapen fruits. This belief is supported by the report of Kaname and Itagi (20) that plants exposed to relatively low temperatures (7^{o}-13^{o}C), just before or just after flower bud differentiation, developed more abnormally-shaped fruits than plants exposed at earlier or later stages. The observation that the problem tends to be emphasized in relatively cool seasons also supports this belief. The literature, however, reveals very little information about the cause of rough fruit.

There have also been reports of the problem occurring in the greenhouse crop in some areas of B.C., especially in the spring crop. The seedlings for the latter crop are started during the cold winter months. Thus, it is suspected that the plants could be unintentionally chilled during some stage or stages of their development resulting in rough fruits. This suspicion is supported by the statement of Stoner (37) in the U.S. Department of Agriculture handbook that "in no case should the night temperature drop below 58^{o}F during fruit bud development, as this may cause misshapen tomatoes of poor quality".

Growers also believe that some cultivars are more susceptible than others to the production of malformed fruit. If this is a fact, it suggests genetic influence on the expression of the character.

The foregoing prompted the initiation of this study to ascertain:

a) What conditions of cool temperature and age of plant resulted in the production of rough fruit, and

b) Whether cultivars (different genotypes) differed in susceptibility to the production of abnormally-shaped fruits.

LITERATURE REVIEW

The production of rough fruit by tomato plants, which have been subjected to relatively cool temperatures during certain periods of their growth, could be due to a disruption of the normal sequence of physiological and developmental processes, which lead to floral initiation, floral development and subsequent fruit set. The disruption could be caused by the relatively cool temperature conditions or by an interaction of the cool temperatures with a complex of other factors. Wedding and Vines (45) stated that although field observations might indicate that a period of poor plant growth and the subsequent production of abnormally-shaped fruit might coincide with a period of exposure to relatively low temperatures, it was impossible to be certain of the relationship. They pointed out that other factors such as sunlight, humidity, nutrient supply and water could be changing at the same time that the plants are exposed to the relatively low temperatures. Kaname and Itagi (20) have since reported that high levels of nutrition and irrigation combined with low temperatures favoured fruit malformation.

Floral Induction and Initiation

There are conflicting results reported on the influence of cultivar (genotype), temperature (both top and root), light, nutrient supply and vegetative growth on floral induction and initiation in the tomato.

There is a sensitive phase for flower production in the tomato plant. Lewis (22) reported that the sensitive period for the temperature effect on the first inflorescence was between the eighth and twelfth day after

cotyledon expansion. Treatments (14°C compared with 25°-30°C) given from the time of cotyledon expansion to the emergence of the first inflorescence had effects which sometimes lasted to the fifth inflorescence. According to Wittwer and Teubner (48), the sensitive interval for the first inflorescence formation was the 2-week period immediately following cotyledon expansion. Similar results were obtained by Calvert (6), who also noted that the sensitive phases for the first, second and third inflorescences occurred at weekly intervals for the cultivar, "Potentate", and at longer intervals for "Ailsa Craig". Frenz (11) growing 3 tomato cultivars under 2 day/night temperature combinations (24°/18° and 18°/12°C) for 18 days after germination, observed that flower initiation occurred 6 to 8 days after germination in some cultivars and after 10 to 12 days in others. However, the end of the sensitive phase, especially with the higher temperatures, could not be clearly shown 18 days after germination.

The relationships among temperature, vegetative growth and flowering were considered by Roodenburg (29) who stated that the number of leaves preceding the first inflorescence emergence was minimal at relatively low temperatures. Wittwer and Teubner (48) also observed that exposure of tomato seedlings to low temperatures (10.0°-12.8°C), in contrast to growth at 18.3°-21.1°C during the sensitive phase, promoted the development of fewer leaves before the first flower cluster appeared. Results obtained by Alpat'eve and Polumordvinova (3) indicated that the initiation of the first inflorescence began 10 to 20 days after germination during the 2 to 3 permanent leaf stage. However, they reported that the temperature during germination and daylength and nutrition during early

growth did not affect the position of the first inflorescence in 6 cultivars, and that the number of leaves preceding the first inflorescence varied from 7 to 10. Calvert (6), using "Potentate", observed that the number of leaves produced before the first inflorescence was minimized with high temperature (26.7 ^{o}C day and night). Later Calvert (7) reported that the duration from germination to the initiation of the first flower truss depended on light and temperature conditions. Temperatures above 21.1 ^{o}C during the vegetative phase significantly increased the number of leaves whereas temperatures below 12.8 ^{o}C slowed down the growth rate of the plant. In further studies, Calvert (8) proposed an explanation and suggested that the rate of apical enlargement was slow at high temperatures because the developing leaves took a greater share of the available assimilates at the expense of the growing point. Thus the transition from vegetative to reproductive activity was delayed. Phatak et al. (26) stated that exposure of the tops of tomato seedlings to temperatures of 10.0^{o}-12.8^{o}C significantly reduced the number of nodes below the first inflorescence when compared with plants grown at 15.6 ^{o}-18.3 ^{o}C or 18.3 ^{o}-21.1 ^{o}C. Aung (4) also observed a relatively high correlation between leaf nodes preceding the first inflorescence and days from seeding to first anthesis. Frenz (11) working with 3 tomato cultivars, which were subjected to 2 day/night temperature combinations (24^{o}/18^{o} and 18^{o}/12^{o}C) for 18 days after germination, concluded that high temperatures, in contrast to relatively low temperatures, resulted in the production of more leaves. However, independent of temperature, the sensitive phase for leaf induction prior to the first inflorescence began 6 days after germination in all cultivars and ended 4 to 6 days

later. Saito and Ito (32) noted that the first inflorescence was differentiated when the stem diameter just below the cotyledon reached 2.4-2.8 mm.

According to Grainger (13) the transition from vegetative to floral activity was effected by an adequate supply of carbohydrates to the growing point. Imanishi and Hiura (19) noted that there were varietal differences in flowering date for the first inflorescence. Lityński and Stankiewicz (24) made a similar observation. However, reports by Calvert (7) showed that the length of the period from germination to the initiation of the first floral truss was dependent on light and temperature conditions. Lewis (22) stated that a low temperature (14°C), compared with high temperatures of 25°-30°C, during the period from cotyledon expansion to the appearance of the first inflorescence, gave an increase in flower number in tomato plants grown under both natural and artificial light. Calvert (5) observed similar results. Verkerk (44) working in California and in Holland noted that under relatively high light conditions, an increase in the average temperatures resulted in fewer flowers per truss; whereas under lower light intensities, the temperature effects were less pronounced. However, Calvert (9) observed that in low light intensities (equivalent to those occurring in mid-winter in Great Britain) an initial period of high temperature (21.1 °C) followed by low temperature (15.6 °C) induced a greater flowering capacity than a constant low temperature. Wittwer and Teubner (48, 49) reported that seedlings, exposed to 10°-13°C in contrast to growth at 18°-21°C for 2 to 3 weeks subsequent to cotyledon expansion, produced a significantly greater number of flowers in the first cluster. Also,

cold treatment of older seedlings increased the flower numbers in later formed clusters. Howlett (17), using the cultivar "WR 7", observed an increase in flower numbers when the plants were grown at 10°C night temperature, but the increase was not substantial, and might have been a varietal effect. Saito and Ito (32) reported that exposure of tomato seedlings to a night temperature of 17°C, in contrast to 24° and 30°C, for 3, 5 and 7 weeks resulted in the production of the maximum number of flowers in the first, second and third inflorescences respectively. In contrast to the above observations, Takahashi et al. (38) stated that more flowers were produced at 24°C than at 17°C. They also observed that floral differentiation was earliest at 30°C and latest at 17°C. Reinken and Struklec (27) also observed earlier flowering at high night temperature (21°C) than at low night temperature (12°C). Differential exposure of the tops and roots of tomato seedlings, according to Phatak et al. (26) showed that top temperatures determined the position of the first inflorescence whereas root temperatures influenced flower numbers. Root temperatures of 10.0°-12.78°C resulted in a significant increase in flower numbers compared with flower production at 15.6°-18.3 °C or 18.3 °-21.11°C. However, Abdelhafeez et al. (2) observed no marked influence of soil temperature on flowering. Howlett (16) has reported that floral primordia were differentiated over a photoperiod of 4 to 24 hours. He obtained no indication that a smaller number of floral primordia was induced and initiated under the shorter photoperiods. White (47) observed that the number of blossom buds formed was lower in nitrogen starved tomato plants than in those receiving adequate nitrogen. Went (46), however, stated that low night temperatures as well as low

light intensities by day, did not materially increase or decrease the number of floral primordia initiated per inflorescence. He stated that flower initiation is primarily a morphological process influenced by internal organization and genetic constitution rather than by external factors.

Floral Development

Hayward (15) stated that the floral primordium first appeared as a dome-shaped enlargement directly continuous with the main axis. The floral parts (calyx, corolla, stamens and pistils) then developed in acropetal succession. The ontogeny of the pistil may indicate how any disruption during this stage of floral development could possibly result in the production of rough fruit. Hayman (15) reported that, in the bicarpellate types of tomato, the early development of the carpellary primordia resulted in the formation of conical hood-like structures whose concave faces opposed each other. Within the carpel primordia there remained a definite proportion of the axis, which consisted of a more or less concave disc. This part of the axis elongated and enlarged to form a conical structure. Later growth was initiated at the base of the elongating cone and 2 septa developed involving a portion of the axis to form 2 locules. At this stage each carpel was open at the top and its cavity was a pit bordered by the elongated central portion of the axis, the ridge-like septa and the curved walls of a carpel. Continued growth resulted in the tip of each carpel being inclined toward the central portion of the axis and finally these tips became so closely appressed to the elongated column of the axis that the 2 structures

were no longer recognizable as distinct from each other. Further elongation of the terminal portions of the carpels resulted in the formation of a long narrow style. Continued enlargement and bowing out of the basal wall of each carpel formed 2 locules in which the central axis developed as a columnar structure from which the ovules arose.

The influence of genotype, temperature, light, water and nutrient supply on the development of the tomato flower has been reported. Mŏskov and Aleksandrova (25) stated that a reduction of night temperature to 17°C retarded bud development. Saito and Ito (32) grew tomato plants under all combinations of day temperatures of 24° and 30° and night temperatures of 17°, 24° and 30°C. They observed that high temperatures induced earlier flower bud development. Calvert (8) also reported that following floral initiation, an increase in both light and temperature tended to accelerate development of the inflorescence towards anthesis. Later, Calvert (9) observed that the beneficial effects on flower development were greatest when the day temperature was high (21.1°C). According to Abdelhafeez et al. (2) flower development was not markedly influenced by soil temperature (20°C) but was retarded by low air temperature (17°C). Howlett (16), using photoperiods of 4-24 hours, concluded that supplemental illumination for tomato plants grown under a short photoperiod resulted in more buds reaching anthesis. Buds tended to absciss on plants grown without extra illumination.

Rylski (30) reported that relatively low temperatures before anthesis caused flower abnormalities. Salvioli and Martín (34) made similar observations. Zielinski (50) described fasciation in the perianth, stamens and pistils of the tomato flower. In the perianth there were exaggerated petal and sepal numbers of up to 80. Both the petals and sepals could be developed in more than one whorl in fasciated flowers. Fasciation in the stamens resulted in adhesion of these organs to the corolla or calyx, cohesion of the antheridial filaments and rudimentary anther sacs with aborted pollen. In the pistil, fasciation showed as partial to complete distortion of the pistillate parts. In the ovary of fasciated flowers, the locules were often increased in number and the ovules were rudimentary and/or aborted. Sometimes as many as 7 pistils were formed in a single flower and frequently at least one of these pistils was functional. This fasciation phenomenon resulted from unfavourable environmental conditions such as relatively low temperatures (7.2^{o}-12.8^{o}C), high nitrogen level, low light intensity and prolonged drought followed by abundant moisture interacting with certain genotypes. Later, Saito and Ito (33) made similar observations on tomato plants exposed to a temperature range of 9^{o}-10^{o}C. They suggested that fasciation was due to surplus nutrients becoming available to the flower buds as a result of reduction in vegetative growth at the low temperature. They, however, observed that this effect was reduced when the plants were grown at low light intensities or under poor nutrient conditions, notably low nitrogen.

Fruit Malformation

There are reports of relationships between abnormal flowers and malformed tomato fruits, and the influence of genotype, temperature and other external factors on the production of misshapen fruit. Shoemaker (35) stated in his book that relatively low temperatures when the fruit clusters were small caused rough fruit. Rylski (30) observed that low temperatures before anthesis in tomato flowers caused flower abnormalities and subsequent fruit deformation. Also using sweet pepper cv. California Wonder (a plant with requirements similar to those for the tomato), Rylski and Halevy (31) reported that a high temperature (20°C) during flower development was a pre-requisite for the formation of well-shaped elongated fruit. Kaname and Itagi (20) also made similar observations, when they exposed tomato seedlings to 4 temperature regimes: 17°-20°C, 7°-10°C, 8°-13°C and cold frame with unregulated temperature during winter in Japan. They reported that the lower the growing temperature, the greater was the production of malformed fruit. A short period (3 days) at 2°C did not affect fruit shape on plants raised as seedlings in normal temperatures. More malformed fruits were developed when plants were exposed to low temperatures just before or just after flower-bud differentiation than when exposed at earlier or later stages. High levels of nutrition and irrigation combined with low temperatures were also found to favour fruit malformation. Working in Morocco, Ricada and Honnorat (28) observed that most of the deformed tomato fruit developed from flowers that were themselves deformed. They stated that these malformations were not inherited and did not resemble those caused by growth regulators. The main cause of

the problem was thought to be climatic since the growing period was marked with unfavourable sandstorms and sharp temperature fluctuations, which resulted in periodic checks of growth. They also suggested that unbalanced nutrient supply might have accentuated the problem in some cases.

Knavel and Mohr (21) grew seedlings of the tomato lines "PI 244956" and "Floralou" for 5 weeks in growth chambers at 2 temperature regimes, 5.6°-13.3°C and 20.0°-26.7°C. Subsequently the plants were transferred to a glasshouse at 20.0°-26.7°C. Most fruits of "Floralou" appeared normal regardless of seedling temperature treatment whereas plants of the "PI" selection grown at 5.6°-13.3°C bore the most deformed fruit of the "catface" type.

Salvioli and Martín (34) reported that the cultivar, "Platense", produced abnormal flowers and excessively large and misshapen fruit of the "catface" type. This character was found to be due to a simple recessive gene afl with complete penetrance at about 10.5°C during flowering and zero penetrance at 20.3°C. Two inherited tomato fruit abnormalities were also reported by Ekstrand (10). The first type was produced from fasciated flowers and such fruits were crinkled and segmented and in some instances had fissures in the pericarp through which the placenta was visible. In the second type of abnormality, the plicate portions of the fruit pericarp did not (as in the first case) form a circle but were irregularly situated within and on top of the normal pericarp structure like a group of small tomatoes on top of a larger main fruit.

It is evident from the foregoing that there is a dearth of reports

giving evidence on the cause of rough fruit. However, if the condition is excited by factors similar to those which cause other fruit abnormalities, eg. "catface", rough fruit may be associated with a complex of factors interacting with certain genotypes to affect vegetative growth and consequently the reproductive capacity and fruitfulness of tomato plants.

MATERIALS AND METHODS

Field and greenhouse experiments were carried out in 1975 and 1976 at the University of British Columbia. The field experiment was located on Department of Plant Science land. The greenhouse experiments were located in a house with automatic roof ventilation, which opened when the temperature reached 18.3 ^{o}C. Most of the greenhouse experiments required periods of controlled temperature regimes, and these periods employed Percival/growth chambers, Model PGC-78, each with a capacity of 75 X 168 X 122 cm and illuminated with 16 high output cool white fluorescent light tubes and 10 40-watt incandescent lamps (42,000 erg/cm^2/sec).

Cultivars/Lines and Source of Seed

A total of 6 different cultivars and 2 reciprocal F_1 hybrids of 2 of the cultivars were used (Table 1).

1. "Bonny Best" (BB). BB was introduced in Philadelphia in 1908 by Johnson and Stokes. It was obtained from a single plant selection of "Chalk Early Jewel" cultivar at Jeffersonville, Pa. It is popular in regions with short growing seasons and it is adapted to all tomato growing regions in the U.S. It is valuable for forcing under glass and matures 63-73 days after setting the plants. BB is used for home and market gardens and it is late in regions of cool nights. BB is a semi-erect indeterminate plant, which grows to a height of 45-55 cm and has a spread of 140-160 cm or 3 times its height.

2. "Cold Set" (CS). CS was introduced by the Douglas Seed Company in Brantford, Canada. It was obtained from a cross between "Fireball"

X wild-fruited "Filipino" number 2 (Pink Selection) at the Ontario Agriculture College, Guelph. It resembles "Fireball" and it is self-pruning and compact. CS has a wide adaptation between the Peace River district of Alberta and Texas. It is excellent for the northern areas with short growing seasons. CS is used for field culture and matures early (68 days). There are both hot and cold setting types and the latter can be seeded direct at soil temperatures as low as 10^{o}C.

3. "Early Red Chief" (ERC). ERC is an early cultivar, which matures 65 days after setting. It is a vigorous compact plant with a long harvest season. The early pickings are shipped and the later harvest is canned.

4. "Fireball" (FB). FB was introduced by the Joseph Harris Company and was announced in the 1952 Harris seed catalogue. It was obtained from "Harris' Round" X "Valiant" and resembles the tomato cultivar "Victor". FB is ideal for field growing in areas with short growing seasons and it is recommended for the Great Lakes region, New England and Canada. The plant is determinate with small vines, little foliage and matures 60-65 days after field-setting. FB produces very smooth globe-shaped fruits and gives large cluster sets even in cold weather.

5. "Immur Prior Beta" (IPB). IPB is an indeterminate tomato cultivar with potato leaves and leafy inflorescence. It produces small fruits with green shoulders and can set fruit at temperatures as low as 7.2 ^{o}C.

6. "Vendor" (VR). VR is one of the best fall staking or greenhouse tomato cultivars. It is slightly shorter than most greenhouse types and is very sturdy. The fruit clusters are closer together than most cultivars.

7. The two reciprocal F_1 hybrids used were IPB X BB and BB X IPB.

Soil Mixes

The soil mixes used to raise all the seedlings are given in Table 2.

Greenhouse Plant Protection

The greenhouse was fumigated every 2 weeks with either "Plantfume" containing Bis-O,O-diethylphosphorothionic anhydride or "Pyrethrum" to control insect pests. The latter fumigant was used whenever it was necessary to avoid flower drop.

A. Field Experiment

The objective of the field experiment was to obtain a quantitative measure of rough fruit production in the different cultivars and F_1 hybrids under field conditions. Cultivars BB, FB, IPB and F_1 hybrids of BB X IPB and IPB X BB were used.

Plant Production

Seeds were sown in flats on April 1, 1975. Seventeen days later the seedlings were pricked-out into 10-cm peat pots. The plants were kept in the greenhouse for another 15 days and then placed in cold frames for hardening for 15 days. The frames were covered at night to guard against frost damage for the first 10 nights, and thereafter only when it was raining.

Table 1. Sources of seed.

Cultivar/Line	Source
Bonny Best (BB)	U.B.C.[z] stock
BB X IPB	U.B.C. stock
Cold Set (CS)	Plant Genetics and Germplasm Inst., Agricultural Research Centre, Beltsville, Maryland 20705, (USDA).
Early Red Chief (ERC)	Stokes Seeds Ltd., St. Catharines, Ontario.
Fireball (FB)	U.B.C. stock
Immur Prior Beta (IPB)	U.B.C. stock
IPB X BB	U.B.C. stock
Vendor (VR)	Stokes Seeds Ltd., St. Catharines, Ontario.

[z]University of British Columbia

Table 2. Soil mixes.

Type of mix	Description
Seed	2 parts screened steam-sterilized soil: 1 part sphagnum moss.
Pricking-out	3 parts screened steam-sterilized soil: 1 part sphagnum moss, plus 1.87 kg "Osmocote" 14-14-14 slow release fertilizer to 1.00 m^3 of the soil-moss mixture.

Planting and Management Practices

The seedlings were transplanted to the field on May 18, 1975 using a randomized complete block design. There were 5 blocks with single row plots, each consisting of 4 plants of one cultivar or hybrid. The spacings were 1.8 m between adjacent blocks and adjacent plots, and 1.2 m within plots.

Immediately after transplanting, the seedlings were protected from arthropod pests with "diazinon" 50EC at the rate of 1 ml l^{-1} of water. Each plant was watered 3 times a week for the first 3 weeks when the plants were getting established and thereafter overhead irrigation was used once a week. The plots were weeded fortnightly. A tri-weekly fertilizer placement programme with a 13-16-10 compound fertilizer at the rate of 277 g to a plant, was started 6 weeks after transplanting. The plants were neither pruned nor trained.

Collection and Treatment of Data

Data on pollen production and fruit shape were collected from the first and second clusters on the main stem.

1. Pollen production. Two of the 4 plants in each plot were randomly selected. The day after the flowers opened, the first 4 flowers of each inflorescence were collected for visual estimation of the amount of pollen produced. Then following acetocarmine (0.5%) staining, the percentage of normal pollen was obtained for each inflorescence.

2. Fruit shape. After randomly selecting the plants for pollen studies, the 2 remaining plants in each plot were used for fruit shape

evaluation. When the flowers opened, each of the 2 clusters was pruned to leave the first 4 flowers to set fruit. The ripe fruits were then graded as:

i) Smooth - symmetrical with no irregularities such that fruits are not noticeably ridged, angular or indented, and marketable (Fig. 1), or

ii) Rough - seriously misshapen or deformed, asymmetrical and unmarketable (Fig. 1)

The pollen and fruit shape data were subjected to standard analyses of variance and the means compared using the Newman-Keuls (SNK) multiple range test when the F-test showed significance at the 1% level.

B. Greenhouse Experiments

1. Experiment 1a

The objective of experiment 1a was to study fruit shape as affected by exposing tomato seedlings to chilling night temperatures. Six cultivars, BB, CS, ERC, FB, IPB and VR were used.

Growing Plants. Seeds were sown on May 16, 1975 and seedlings pricked-out into 10 - cm plastic pots 11 days later. Chilling treatments were started on June 11, 1975, and 17 days later the seedlings were transferred to 15 - cm pots and chilling treatments were continued for a further 14 days.

Chilling Treatment. The chilling treatments were intended to simulate the growing conditions under which tomato plants are alleged to develop rough fruit, that is chilling at night, whether the plants be in protected structures or in the field. Thus, during the treatment period,

Fig. 1. Smooth, moderately rough and rough fruits.

the plants were placed in the growth chambers each day from 2000 h to 0800 h, and returned to the greenhouse for the remainder of the day. The night temperatures employed were $10^{o}\pm1^{o}C$ (cool chamber) for the chilling treatment and $19^{o}\pm1^{o}C$ (warm chamber) for the control or non-chilling conditions.

The possible relationship between age of plant and vulnerability to chilling treatment was studied by choosing 4 different ages for the test plants. Thus treatment of different age lots began at 3.5, 4.5, 5.5 and 6.5 weeks after seeding. Each age group was subjected to 3 durations of exposure to the chilling temperature:

a) No chilling - 7 nights in the warm chamber;

b) Short chilling - 3 nights in the cool chamber and 4 nights in the warm chamber;

c) Long chilling - 7 nights in the cool chamber.

Six plants of each cultivar were chosen at random for each duration of exposure for each age-of-plant lot. Over the 7-day treatment period, the seedlings were moved around in the growth chambers so that no plant occupied the same position for 2 successive nights. Plants belonging to the same age lot were placed together randomly at one place on a greenhouse bench at the end of the treatment period.

Planting and Management Practices. Four uniform seedlings out of the 6 treated at each age were selected for each cultivar and each duration of treatment at the end of the last treatment age (7.5 weeks after seeding). The plants were then potted in 9 l2 plastic buckets filled with steam-sterilized soil. Four greenhouse benches were used as replications with

72 single plant plots. The table of random numbers (23) was used to position plots within each replicate.

The plants were trained to a single stem and watered daily. A fortnightly fertilizer programme with "Hi-sol" 20-20-20 soluble plant food at 2 g per plant was started 2 weeks after potting.

Collection and Treatment of Data. Data were collected separately for the first and second inflorescences.

1. Number of flowers. The total number of flowers was counted when the last floral bud in each inflorescence became visible.

2. Relationship between flower morphology and fruit shape. An attempt was made to relate the flower appearance to the shape of the fruit which would subsequently develop from it. Ninety-four plants from the 4 replications (26, 27, 21 and 20 plants from replications 1 to 4 respectively) were randomly selected 5 to 6 weeks after seeding. All the flowers which were open within this period were classified and tagged as:

i) normal:- anther cone symmetrical and all other floral parts not fasciated, expected to produce smooth fruit;

ii) semi-normal:- anther cone slightly misshapen and/or enlarged, some of the other floral parts fasciated, expected to produce moderately rough fruit, and

iii) abnormal:- anther cone asymmetrical and fasciated, and most or all the other floral parts fasciated, expected to produce rough fruit.

3. Fruit number and shape. The total number of fruits retained in each cluster was counted at maturity. The ripe fruits were then graded as

rough, moderately rough, or smooth.

Data on flower and fruit numbers and on fruit shape were subjected to standard analyses of variance and the means compared using the SNK test when the F-test showed significance at the 1% level.

2. Experiment 1b

The trial was intended as a supplement to experiment 1a to estimate the number of days taken for the first and second inflorescences to appear in the different cultivars.

Growing Plants. Plants were taken from the same seedling lot raised for experiment 1a. The plants were set on a greenhouse bench using 3 replications in a completely randomized block design. No chilling treatments were given and all other cultural practices were the same as those used in experiment 1a.

Collection and Treatment of Data. Flower Initiation. The number of days from seeding to the first flower bud emergence was noted for the first and second clusters. The means of 2 plants per cultivar per replication were subjected to the standard analysis of variance. The cultivar and cluster means were each compared with the SNK test when the F-test showed significance at the 1% level.

3. Experiment 2

The results from experiment 1a indicated that the chilling treatments employed had little effect on fruit shape. Some surplus young plants for the

field experiment had been placed in cold frames for 3 weeks in May, 1975, and were then returned to the greenhouse where they subsequently produced a considerable number of rough fruit on early clusters. This contrast suggested that a more severe chilling treatment might be associated with production of rough fruit, and that the age of plant or stage of development might be important. Thus, experiment 2 was designed to study the effect of exposing tomato seedlings at different ages to relatively severe chilling temperatures below 12.8 ^{o}C continuously for a period of 2 weeks, thereafter placing the plants in normal greenhouse growing temperatures of 20^{o}C and above. Four cultivars were chosen for test in this experiment, namely, CS, FB, IPB and VR.

Growing Plants. Seeds were sown on May 4, 1976 and seedlings pricked-out into 10 cm square plastic pots 8 days later. The plants were kept in the greenhouse for another week to recover from the shock of pricking-out and then placed in the growth chambers. There was a total of 25 plants per cultivar and each plant was numbered to indicate the position it was to occupy in the growth chamber using the table of random numbers (23).

Chilling Treatment. The chilling treatment was exposure of plants to a diurnal temperature range of 4.4^{o} to 12.8^{o}C for a period of 2 weeks. The control plants were kept on a diurnal temperature range of 20.0^{o} to 23.9^{o}C. When the plants were in the controlled environment chambers, a 14-hour photoperiod was supplied as follows:

0600 h to 0700 h - all incandescent lamps on;

0700 h to 0930 h - all incandescent and half fluorescent lamps on;

0930 h to 1700 h - all incandescent and fluorescent lamps on;

1700 h to 1830 h - all incandescent and half fluorescent lamps on;

1830 h to 2000 h - all incandescent lamps on;

2000 h to 0600 h - all lights off.

A total of 3 growth chambers, 2 programmed to give normal temperatures (20.0°-23.9°C) and a third set to give cool temperatures (4.4°-12.8°C) were used. Diurnal changes in temperature from hour to hour were gradual.

One week after pricking-out, when the plants were assumed to have recovered from the shock of pricking-out, the seedlings were transferred to one normal-temperature growth chamber for one week to enable them to adjust to the growth chamber growing conditions. The chilling treatments were then begun. There were 5 treatment groups which included 4 groups of chilling treatments and a fifth group was the unchilled control. Each chilling treatment group was placed in the cool-temperature growth chamber for a 2-week period of continuous chilling. Thus the treatment groups were:

1) Chilling started at 3 weeks from seeding;

2) Chilling started at 4 weeks from seeding;

3) Chilling started at 5 weeks from seeding;

4) Chilling started at 6 weeks from seeding;

5) No chilling - control.

The order in which the plants were placed in the 3 growth chambers is shown in Table 3.

The same number of seedlings was kept in all the chambers at any given time by the use of filler plants in order to eliminate border effects and to ensure the same chamber area for each plant. Thermographs and

Table 3. Location of the plants in the 5 treatment groups from pricking-out to transplanting.

Weeks after pricking-out	Growth chamber		
	Normal		
	1	2	Cool
0	All plants in greenhouse		
1	trt[Z] 1,2,3,4,5	-	-
2	trt 2,3,4,5	-	trt 1
3	trt 3,4,5	-	trt 1,2
4	trt 4,5	trt 1	trt 2,3
5	trt 5	trt 1,2	trt 3,4
6	trt 3,5	trt 1,2	trt 4
7	All plants in greenhouse		

[Z]Treatment group as listed on page 24.

minimum and maximum thermometers were kept in the growth chambers to check the temperatures.

Planting and Management Practices. The chilling treatments were ended on July 1, 1976 and all the plants returned to the greenhouse, then 4 uniform plants were selected out of the 5 plants per cultivar in each treatment group and planted in 9:1 plastic containers filled with steam-sterilized soil on July 2, 1976. The same randomization order which

was kept in the growth chambers was maintained in the greenhouse.

Each plant was grown to a single stem and staked. Plants were watered daily and fed with approximately 1 g "Hi-sol" 20-20-20 per plant once a week starting from 2 weeks after potting.

Collection and Treatment of Data. Data were collected on the first 4 clusters.

1. Flower initiation. The number of days from seeding to the appearance of the first floral bud was noted for each of the 4 inflorescences.

2. Fruit set. The number of days taken for the first fruit to set on each cluster was recorded. The flower was considered to have set fruit when the ovary developed to the size of a pea. Two sets of data were recorded:

i) days from seeding to first fruit set; and

ii) days from first flower bud appearance to first fruit set.

3. Relationship between flower morphology and fruit shape. An attempt was made to relate the flower appearance to the shape of the fruit which would subsequently develop from it. The flowers were classified as normal, semi-normal or abnormal based on the criteria used in experiment 1a.

4. Fruit number and shape. The total number of fruits retained in each cluster was counted at maturity. The ripe fruits were then graded as smooth, moderately rough or rough.

All data were evaluated as outlined for experiment 1. It was intended to test the relationship between flower morphology and subsequent fruit shape, but the proportions of flowers in the semi-normal and abnormal groups were comparatively too low to warrant using the X^2 test.

4. Experiment 3

The objective of the greenhouse experiment 3 was to study fruit shape as affected by exposing tomato plants to temperatures which fluctuated in contrast to the uniform or gradually changing temperature regimes employed in previous experiments. Two cultivars, IPB and VR, were used.

Growing Plants. Seeds were sown on August 23, 1976 and seedlings pricked-out 8 days later into 10 cm plastic pots. The plants were kept in the greenhouse and transferred to the growth chambers on September 27, 1976, 35 days from seeding, after the plants were potted into 9 l plastic buckets filled with steam-sterilized soil.

Temperature Treatment and Management Practices. Two temperature regimes were used: i) warm regime - gradual change in temperature with a day high of 23.9 °C at noon and a night low of 20.0 °C at midnight; ii) cool regime - sharp hourly fluctuations of temperature between a day high of 21.1 °C at noon and a night low of 4.4 °C at 0100 h. A 14-hour photoperiod from 0600 h to 2000 h was given as done in experiment 2.

There were 4 plants per cultivar, arranged randomly in each growth chamber. The plant positions were changed each week to minimize position effects on growth. Each plant was fertilized with 14.2 g "Hi-sol" 20-20-20 fertilizer before being placed in the growth chamber. Three weeks after treatment was started, each plant was fertilized with 28.4 g of a fertilizer mixture made up of equal volumes of KNO_3 and Superphosphate (KNO_3: N=13.5%, K_2O = 46%, and Superphosphate = 18% P_2O_5), and this treatment was repeated every 3 weeks. The plants were trained to a single stem.

Collection and Treatment of Data. The total number of fruits were counted at maturity in clusters 1 to 4. The fruits were then graded as smooth, moderately rough and rough. Data were evaluated as for the previous experiments.

RESULTS

In general, with the exception of the field data, the number of malformed fruit produced was comparatively too few for any significance between lines to be of real value. Rough fruit production was not shown to be influenced by relatively cool temperatures in the controlled experiments.

Field Experiment

There were several occurrences which affected the data collected.

1. Bonny Best (BB). The tops of 2 plants (one each from blocks 1 and 5) died before fruit set. The remaining plants had either no set or only 1 fruit set instead of the expected 4 in cluster 1. Fruit set was, however, improved on the second cluster with only 1 plant not setting any fruit. The means of percentage set were 15.6% on cluster 1 and 50% on cluster 2.

2. Fireball (FB). Two of the total of 10 plants did not set any fruit on cluster 2, but cluster 1 set some fruit on all plants. Mean percentage fruit sets were 67.5% and 52.5% on clusters 1 and 2 respectively.

3. Both inflorescences set fruit in the other lines. IPB averaged 100% on both trusses. BB X IPB had means of 87.5% and 92.5% fruit set respectively on the first and second clusters. IPB X BB had 97.5% set on cluster 1 and 100% set on cluster 2.

Pollen Production and Percent Normal Pollen. Pollen production by FB was relatively poor; however, the other lines produced relatively large

quantities of pollen and there were no apparent differences among them.

The percentages of normal pollen showed no significant differences among the lines (Table 4). There was, however, an indication that IPB and IPB X BB produced the lowest proportions of normal pollen. The percentages of normal pollen produced by BB, BB X IPB and FB were very similar (Table 5).

Total Number of Fruit. The total number of fruits produced on both the first and second clusters showed significant differences among lines (Table 6). The highest yields on cluster 1 were obtained from IPB, IPB X BB and BB X IPB but the differences between them were not significant. FB gave an average fruit yield, which was not significantly different from the yield of BB X IPB, but significantly different from IPB and IPB X BB (Table 7). BB produced significantly fewer fruits in cluster 1 than any of the other lines.

IPB, IPB X BB and BB X IPB as a group produced significantly more fruit on cluster 2 than either FB or BB. The difference between the latter 2 lines was not significant, and differences among the former lines were also not significant.

Number of Smooth Fruit. Yields of smooth fruit showed significant differences for cluster 2 but not for cluster 1 (Tables 6 and 7). There were no smooth fruits on either cluster of IPB and cluster 1 of BB (Table 7). The only significant difference in yields of smooth fruit was that between IPB and BB X IPB on cluster 2.

Number of Rough Fruit. There were significant differences among lines in rough fruit numbers on both clusters (Table 6). Only the differences

Table 4. Analyses of variance of the mean[z] percent normal pollen per plant on clusters[y] 1 and 2.

Source	Df	Mean squares	
		Cluster 1	Cluster 2
Rep	4	77.86	102.52*
Lines[x]	4	131.69	94.82*
Error	16	85.26	29.07
Total	24		

[z]Mean of 2 plants per line per replication.
[y]Each cluster analyzed separately.
[x]Lines indicate 3 cultivars and 2 F_1 reciprocal hybrids.
*Significant, at the 5% level.

Table 5. Mean[z] percent normal pollen per plant of each line[y] on clusters[x] 1 and 2.

Cluster	Lines (% normal pollen)				
	BB	BB X IPB	IPB	IPB X BB	FB
1	85.6[w]	83.3	77.9	73.4	84.4
2	87.4	86.8	77.8	81.1	87.1

[z]Mean of 10 plants in all lines except BB (8 plants).
[y]Line indicates 3 cultivars and 2 F_1 reciprocal hybrids.
[x]Each cluster analyzed separately.
[w]The SNK test was not carried out after the analysis of variance showed no significance, 1% level.

Table 6. Analyses of variance of the mean numbers of total, smooth and rough fruit per plant of each line[z] on clusters[y] 1 and 2.

		Mean Squares					
		Cluster 1			Cluster 2		
Source	Df	Total	Smooth	Rough	Total	Smooth	Rough
Rep (R)	4	0.125	2.178**	1.917	0.632	0.295	0.839
Lines (V)	4	17.870**	3.167	14.128**	9.729**	2.220**	10.228**
R X V	16	0.406	1.518**	1.633**	0.811	0.464	0.846
Error	23	0.283	0.435	0.500	1.022	0.587	1.565
Total	47						

[z]Line indicates 3 cultivars and 2 F_1 reciprocal hybrids.

[y]Each cluster analyzed separately.

**Significant, 1% level.

Table 7. Mean[z] number of total, smooth and rough fruit per plant of each line[y] on clusters[x] 1 and 2.

		Total fruit number		Smooth fruit number		Rough fruit number	
Line	Cluster	1	2	1	2	1	2
BB		0.5c[w]	2.0b	0.0	0.5ab	0.5b	1.5b
BB X IPB		3.5ab	3.7a	1.2	1.2a	2.3ab	2.5b
IPB		4.0a	4.0a	0.0	0.0b	4.0a	4.0a
IPB X BB		3.9a	4.0a	1.1	1.0ab	2.8a	3.0ab
FB		2.7b	2.1b	0.5	0.5ab	2.2ab	1.6b

[z]Mean of 10 plants in all lines except BB (8 plants).

[y]3 cultivars and 2 F_1 reciprocal hybrids.

[x]Each cluster analyzed separately.

[w]Mean separation within columns by SNK test, 1% level. Absence of a letter shows the test was not carried out after the analysis of variance showed no significance, 1% level.

between BB and each of IPB and IPB X BB were significant on the first cluster (Table 7). The differences between IPB and every other line but IPB X BB were significant in cluster 2.

One hundred percent of the IPB fruits were rough on both clusters. BB produced 100% rough fruit on cluster 1 but 25% less rough fruit on cluster 2. With IPB as the maternal parent, the F_1 hybrid with BB had 71.8% and 75.0% rough fruit respectively on the 2 clusters. The reciprocal hybrid gave about 65.7% rough fruit on cluster 1 and about 1.9% more on cluster 2. FB produced about 81.5% rough fruit on the first cluster and 76.2% on the second cluster.

Greenhouse Experiments

Experiment 1a

Number of Flowers. The number of flowers produced differed significantly among cultivars (Table 8). IPB and BB produced the most flowers and the difference between them was significant (Table 9). The differences between each of these 2 cultivars and the other cultivars were also significant. However, the differences among the number of flowers produced by CS, ERC, FB and VR were not significant.

Neither the age at which the plants were chilled nor the duration of the chilling treatment had any significant effects on the number of flowers produced (Table 8). Cluster 1 produced more flowers than cluster 2 but the difference was not significant. Also, there were no significant interactions among any of all the main effects.

Total Number of Fruit. Considering total fruit number, the cultivars

Table 8. Analyses of variance of the numbers of flowers, total, smooth, moderately rough and rough fruits per plant.

Source		Mean squares				
		Flowers	Total fruit	Smooth fruit	Moderately rough fruit	Rough fruit
Replications	3	3.590	9.557	7.150	2.447	0.928
Age (A)	3	5.682	2.997	9.243	0.271	1.660
Cultivars (C)	5	116.160**	209.390**	244.970**	3.794*	4.261**
Treatments (T)	2	0.866	2.314	0.470	0.825	0.049
A X C	15	3.884	2.380	2.976	1.264	1.069
A X T	6	1.922	4.428	5.748	0.929	0.674
C X T	10	3.637	4.062	4.268	0.625	0.184
A X C X T	30	2.157	3.542	4.596	0.768	0.790
Error (A)	213	3.402	3.291	4.781	1.267	0.797
Clusters (P)	1	10.293	77.293**	26.694**	4.340*	2.778**
P X A	3	0.354	17.650**	11.745**	1.419	0.199
P X C	5	6.239	17.685**	13.336**	0.919	0.490
P X T	2	1.616	0.283	0.137	0.116	0.028
P X A X C	15	1.560	4.097	3.587	1.604**	0.445
P X A X T	6	1.440	1.938	1.632	0.619	0.463
P X C X T	10	2.450	2.206	2.473	0.458	0.234
P X A X C X T	30	2.910	3.483	3.068	0.599	0.311
Error	216	2.958	2.433	2.332	0.682	0.264
Total	575					

*Significant, 5% level

**Significant, 1% level

Table 9. Mean[z] number of flowers per plant of each cultivar.

Cultivar	BB	CCS	ERC	ERC FL	FB	IPB	VR
Number of flowers	8.35b[y]	6.98c	6.64c	7.28c	9.40a	6.68c	

[z]Mean of clusters 1 and 2.

[y]Mean separation within row by SNK test, 1% level.

could be separated into 3 significantly different groups (Table 10). BB and IPB gave the highest yields and the poorest were obtained from ERC and VR. Fruit yields of CS and FB were intermediate between the previous groups and the differences within groups were not significant.

Mean fruit number on cluster 1 was significantly greater than on cluster 2, but mainly in IPB and VR (Tables 8 and 10). Although the age at which the plants were chilled did not significantly influence fruit number, there was a significant interaction between age and cluster (Table 8). The differences between the 2 clusters of plants chilled at 5.5 and 6.5 weeks of age were significant (Table 11).

Duration of exposure to cold temperature did not significantly affect yield and there were no interactions between treatment duration and the other main effects (Table 8).

Number of Smooth Fruit. There were significant differences in the number of smooth fruit among cultivars (Table 8). IPB and BB respectively had the highest and the second highest mean numbers of smooth fruit per cultivar, and the difference between them was significant (Table 12). The lowest numbers of smooth fruit were obtained from ERC and VR but the difference between them was not significant.

The mean number of smooth fruit was greater on cluster 1 than on cluster 2, and the difference was significant (Table 12). There was a significant cultivar X cluster interaction but only the differences between the clusters on IPB and VR were significant (Tables 8 and 12). Age at treatment initiation did not affect numbers of smooth fruit but an age X cluster interaction resulted in significant differences between clusters on plants chilled at 5.5 and 6.5 weeks of age (Tables 8 and 13).

Table 10. Mean total number of fruit per plant of each cultivar on clusters 1 and 2.

Cluster	Cultivar						Cluster mean
	BB	CS	ERC	FB	IPB	VR	
1	6.31ab[z]	3.81cd	3.08de	3.85cd	7.10a	3.85cd	4.67a[x]
2	5.62b	3.75cd	2.44e	4.27c	5.38b	2.17e	3.94b
Cultivar mean	5.97a[y]	3.78b	2.76c	4.06b	6.24a	3.01c	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 11. Mean total number of fruit per plant per treatment age[z] on clusters 1 and 2.

Cluster	Treatment age (weeks)				Cluster mean
	3.5	4.5	5.5	6.5	
1	4.43bc[y]	4.24bc	4.75ab	5.26a	4.67a[x]
2	4.11bc	4.25bc	3.62c	3.76c	3.94b

[z]Age (from seeding) at which chilling treatment was initiated.

[y]Mean separation within and between columns by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 12. Mean number of smooth fruit per plant of each cultivar on clusters 1 and 2.

Cluster	Cultivars						Cluster mean
	BB	CS	ERC	IPB	FB	VR	
1	4.67b[z]	2.56cd	1.35e	6.02a	2.73cd	2.31d	3.27a[x]
2	4.23b	2.60cd	1.04e	4.71b	3.38c	1.10e	2.84b
Cultivar mean	4.45b[y]	2.58c	1.20d	5.36a	3.05c	1.71d	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 13. Mean number of smooth fruit per plant per treatment age[z] on clusters 1 and 2.

Cluster	Treatment age (weeks)				Cluster mean
	3.5	4.5	5.5	6.5	
1	3.21ab[y]	2.92bc	3.18ab	3.79a	3.27a[x]
2	3.08ab	3.14ab	2.28c	2.88bc	2.84b

[z]Age (from seeding) at which chilling treatment was initiated.

[y]Mean separation within and between columns by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Number of Moderately Rough Fruit. The analysis of variance showed no dependence of moderately rough fruit production on any of the main effects, namely, cultivar, cluster, age at chilling and duration of the chilling treatment (Table 8). There was, however, a significant third order interaction effect among cultivar, cluster, and age at chilling (Table 14).

Number of Rough Fruit. Rough fruit number indicated significant differences among cultivars and between clusters (Table 8). Cluster 1 had more rough fruit than cluster 2 (Table 15).

BB had the most rough fruit and the differences between that cultivar and ERC and VR were not significant (Table 16). The smallest number of rough fruit was given by CS but only the differences with BB and VR were significant.

The analysis of variance (Table 8) showed that the chilling treatments did not result in any significant differences in the numbers of rough fruit on the several cultivars.

Flower Morphology and Fruit Shape. It was intended to test the relationship between flower appearance and subsequent fruit shape, but the proportions of flowers in the semi-normal and abnormal groups were comparatively too low to warrant using the X^2 test.

The relationship between normal flowers and subsequent smooth fruit yield may be considered to be quite high by inspection of the data (Table 17), whereas that between abnormal flowers and rough fruit production is fair.

Table 14. Mean number of moderately rough fruit per plant of each cultivar per treatment age[z] on clusters 1 and 2.

Age (weeks)	Cluster	Cultivar					
		BB	CS	ERC	FB	IPB	VR
3.5	1	0.417ab[y]	1.667a	1.417ab	0.583ab	1.167ab	0.500ab
	2	0.917ab	0.750ab	1.250ab	0.917ab	0.250ab	0.833ab
4.5	1	1.167ab	0.500ab	1.250ab	1.333ab	0.250ab	1.083ab
	2	1.167ab	1.000ab	1.333ab	0.833ab	0.500ab	0.750ab
5.5	1	1.167ab	1.083ab	1.250ab	1.167ab	0.750ab	0.833ab
	2	1.250ab	1.250ab	0.667ab	1.000ab	0.833ab	0.667ab
6.5	1	0.750ab	1.083ab	1.750a	1.000ab	0.917ab	1.417ab
	2	0.583ab	1.333ab	0.917ab	0.417ab	0.833ab	0.083b
Cultivar means		0.927[x]	1.083	1.229	0.906	0.688	0.771

[z]Age (from seeding) at which chilling treatment was initiated.

[y]Mean separation within and between columns by SNK test, 1% level.

[x]SNK test was not carried out after the analysis of variance showed no significance, 1% level.

Table 15. Mean number of rough fruit per plant on clusters 1 and 2.

Cluster	Number of rough fruit
1	0.385a[z]
2	0.246b

[z]Mean separation within column by SNK test, 1% level.

Table 16. Mean number of rough fruit per plant of each cultivar.

Cultivar	BB	CS	ERC	FB	IPB	VR
Number of rough fruit	0.594a[z]	0.115c	0.333abc	0.125c	0.188bc	0.542ab

[z]Mean separation within row by SNK test, 1% level.

Table 17. Numbers of normal[z], semi-normal[y] and abnormal[x] flowers and the subsequent smooth, moderately rough and rough fruits observed.

	Normal flower	Smooth fruit	Semi-normal flower	Moderately rough fruit	Abnormal flower	Rough fruit
Number	196.00	180.00	39.00	65.00	28.00	8.00
% of total number	74.52	68.44	14.83	24.71	10.65	6.84

[z]Normal flower expected to yield smooth fruit.

[y]Semi-normal flower expected to yield moderately rough fruit.

[x]Abnormal flower expected to yield rough fruit.

Experiment 1b

Flower Initiation. Differences between the days from seeding to the appearance of the first and second inflorescences and also differences among cultivars were shown to be significant (Tables 18 and 19).

IPB was the earliest and ERC and VR were the latest to show floral buds. The differences between IPB and each of the latter cultivars were significant (Table 19). The difference between CS and VR was also significant. The difference between ERC and VR and the differences among BB, CS and FB were not significant. There was an indication at the 5% level that the cultivar X cluster interaction had an effect on the period required for flower bud appearance (Table 18).

Experiment 2

Flower Initiation. There were significant differences among cultivars for the period required from seeding to appearance of the first floral buds (Table 20). Means in Table 21 show FB and CS were the earliest but the difference between them was not significant. IPB was significantly later than FB and CS and in turn VR was significantly later than IPB. Also there were significant differences in the cultivar X cluster interaction effects (Tables 20 and 21).

Earliness or lateness of flower bud appearance was significantly affected by the age at chilling (Table 22). Chilling (treatment) at 3 and 4 weeks from seeding significantly delayed floral bud appearance compared to the control and treatment at 5 and 6 weeks of age. Some treatment X cultivar interaction effects were shown to be significant (Tables 20 and 22). The cluster X treatment X cultivar interaction effects

Table 18. Analysis of variance of mean[z] numbers of days from seeding to appearance of first flower buds on clusters 1 and 2 of each cultivar.

Source	Df	Mean square
Replication	2	0.0625
Cultivars (C)	5	46.2125**
Error (c)	10	3.3375*
Clusters (P)	1	925.1736**
P X C	5	4.3569*
Error	12	0.9309
Total	35	

[z]Mean of 2 plants per cultivar per replication

*Significant, 5% level.

**Significant, 1% level.

Table 19. Mean number of days from seeding to appearance of first flower buds on clusters 1 and 2 of each cultivar.

Cluster	Cultivar (days)						Cluster means
	BB	CS	ERC	FB	IPB	VR	
1	30.2[z]	29.5	33.5	29.8	27.2	32.7	30.5b[x]
2	39.8	37.7	46.2	38.3	38.3	43.3	40.6a
Cultivar means	35.0bc[y]	35.6c	39.8a	34.1bc	32.8c	38.0ab	

[z]Absence of a letter shows the SNK test was not carried out after the analysis of variance showed no significance, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 20. Analyses of variance for mean numbers of days from seeding to appearance of first flower buds, and for first fruit set and days from first flower bud appearance to first fruit set on clusters 1 to 4.

Source	Df	Mean squares		
		First flower bud appearance	First fruit set	First flower bud appearance to first fruit set
Cultivar (C)	3	2356.80**	1210.70*	263.18
Treatment (T)	4	416.48**	659.22	1012.40**
C X T	12	68.85	435.69	130.06
Pl/C X T	59	38.27**	371.19	115.46
Cluster (P)	3	8973.60**	2500.10**	1352.90**
P X C	9	352.60**	1281.70**	434.48**
P X T	12	54.94**	442.89	198.37*
P X C X T	36	16.56**	439.83*	107.22
Error	177	8.81	286.20	97.22
Total	315			

[z]Plants

*Significant, 5% level

**Significant, 1% level

Table 21. Mean number of days from seeding to appearance of first flower buds on clusters 1 to 4 per plant of each cultivar.

Cluster	Cultivar				Cluster means
	CS	FB	IPB	VR	
1	29.4h[z]	28.8h	27.6h	33.2g	29.8d[x]
2	38.3c	35.2g	41.1f	44.6e	39.8c
3	43.0ef	41.2f	51.8d	53.4d	47.4b
4	45.8e	45.0e	61.4b	65.8a	54.6a
Cultivar means	39.1c[y]	37.6c	45.5b	49.2a	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 22. Mean number of days from seeding to appearance of first flower buds on clusters 1 to 4 per plant at each treatment[z]

Treatment (weeks)	Cluster 1	2	3	4	Treatment means
3	35.4e[y]	43.6d	50.1c	55.2a	46.1a[w]
4	29.1f	44.5d	50.8bc	56.5a	45.2a
5	27.5f	36.2e	46.9d	54.7a	41.3b
6	28.7f	37.5e	44.6d	53.2ab	41.0b
Control	27.9f	37.0e	44.3d	53.5ab	40.7b
Cluster means	29.8d[x]	39.8c	47.4b	54.6a	

[z]Age (from seeding) at which chilling treatment was initiated.

[y]Mean separation within and between columns by SNK test, 1% level.

[x]Mean separation within row by SNK test, 1% level.

[w]Mean separation within column by SNK test, 1% level.

were also significant.

Fruit Set. Differences between the number of days from seeding to first fruit set on the first 4 clusters were significant (Table 23). However, only the differences between the first cluster and each of clusters 3 and 4 were shown to be significant.

There was an indication (5% level) that earliness or lateness of first fruit set depended on the cultivar (Table 20). However, cultivar X cluster interaction effects were shown to be significant (Table 23). The number of days from seeding to first fruit set was unaffected by chilling at any age (Table 20).

Mean Number of Days from First Flower Bud Appearance to First Fruit Set. The effect of chilling at the different ages on the number of days required between first floral bud appearance and first fruit set was significant (Table 20). Chilling at 5 and 6 weeks, in contrast to the control and treatment at 3 and 4 weeks, significantly delayed fruit set (Table 24).

The time required for the first fruit to set after first floral bud appearance showed significance among clusters (Table 20). The period for the first cluster was significantly greater than for clusters 2, 3 and 4 and the differences among the latter 3 clusters were not significant (Table 24). There was an indication at the 5% significance level of treatment X cluster interaction effects on the number of days required to set the first fruit after first floral bud appearance (Table 20). This period was not affected by cultivar but there was a significant cultivar X cluster interaction effect (Tables 20 and 25).

Total Number of Fruit. The total numbers of fruit per plant showed

Table 23. Mean number of days from seeding to first fruit set on clusters 1 to 4 per plant of each cultivar.

Cluster	Cultivar				Cluster means
	CS	FB	IPB	VR	
1	54.5b[z]	58.2b	66.9ab	64.2ab	61.0b[x]
2	63.9ab	59.4b	70.6ab	69.0ab	65.8ab
3	69.8ab	69.8ab	72.6ab	81.2a	73.4a
4	74.2ab	73.8ab	84.5a	53.6b	71.5a
Cultivar means	65.6[y]	65.3	73.6	67.0	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Absence of a letter in row shows the SNK test was not carried out after the analysis of variance showed no significance, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 24. Mean number of days from first flower bud appearance to first fruit set on clusters 1 to 4 per plant at each chilling treatment[z]

Treatment (weeks)	Cultivar 1	2	3	4	Treatment means
3	27.1[y]	22.9	21.6	23.7	23.8b[w]
4	36.1	23.2	21.4	21.1	25.4b
5	40.9	34.1	30.5	22.6	32.0a
6	33.1	34.6	33.4	27.6	32.2a
Control	29.8	23.3	26.3	22.6	25.5b
Cluster mean	33.4a[x]	27.7b	26.6b	23.5b	

[z]Age (from seeding) at which chilling treatment was initiated.

[y]Absence of a letter shows the SNK test was not carried out after the analysis of variance showed no significance, 1% level.

[x]Mean separation within row by SNK test, 1% level.

[w]Mean separation within column by SNK test, 1% level.

Table 25. Mean number of days from first flower bud appearance to first fruit set on clusters 1 to 4 per plant of each cultivar.

Cluster	Cultivar				Cluster means
	CS	FB	IPB	VR	
1	29.6c[z]	30.7c	40.7a	32.6c	33.4a[x]
2	27.5c	27.5c	29.4c	26.2c	27.7b
3	26.8c	28.6c	23.4c	27.8c	26.6b
4	28.4c	28.8c	23.1c	14.1b	23.5b
Cultivar means	28.1[y]	28.9	29.2	25.2	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Absence of a letter in row shows the test was not carried out after the analysis of variance showed no significance, 1% level.

[x]Mean separation within column by SNK test, 1% level.

significant differences among cultivars (Table 26). IPB had the most fruit and the differences with the other cultivars, CS, FB and VR, were significant (Table 27). However, none of the differences among the later 3 cultivars was significant.

There were indications at the 5% significance level of cluster differences and cluster X cultivar interaction effects on total fruit number (Table 26). Chilling the plants at the various ages did not significantly affect fruit number but there was an indication (5% level) of cluster X cultivar within treatment interaction effect (Table 26).

Number of Smooth Fruit. The numbers of smooth fruit per plant showed significant differences among cultivars and among clusters (Table 26). IPB produced the most smooth fruit and the differences between IPB and the other cultivars, CS, FB and VR, were significant (Table 28). The differences among the latter 3 cultivars were not significant.

The second cluster yielded significantly more smooth fruit than the other 3 clusters (Table 28). The differences among the first, third and fourth clusters were not significant. The cultivar X cluster interaction effects showed significance (Tables 26 and 28), and smooth fruit number was not affected by the chilling treatments (Table 26).

Number of Moderately Rough Fruit. The number of moderately rough fruit significantly depended on the cultivar (Table 26). The greatest number was produced by IPB and it was significantly different from the yields of CS, FB and VR (Table 29). The differences among the latter 3 cultivars were not significant. Although the differences among clusters did not show any significance, the cultivar X cluster interaction effects were significant. Chilling the plants did not significantly affect

Table 26. Analysis of variance of numbers of total smooth, moderately rough and rough fruit per plant.

Source	Df	Mean squares			
		Total fruit	Smooth fruit	Moderately rough fruit	Rough fruit
Cultivar (C)	3	157.69**	76.48**	14.62**	0.403*
Treatment (T)	4	4.07	4.65	1.42	0.169
C X T	12	4.57	5.30	1.20	0.162
Plants/C X T	59	2,83	2.84	1.24**	0.145
Cluster (P)	3	10.69*	19.94**	1.34	0.079
P X C	9	5.45*	11.65**	2.78**	0.096
P X T	12	4.67	4,54*	1.53*	0.274*
P X C X T	36	4.24*	2.84	1.02	0.187
Error	177	2.76	2.14	0.74	0.134
Total	315				

*Significant, 5% level.

**Significant, 1% level.

Table 27. Mean total number of fruit per plant of each cultivar on clusters 1 to 4.

Cluster	Cultivar				Cluster Means
	CS	FB	IPB	VR	
1	2.42[z]	2.75	5.25	3.10	3.39[y]
2	3.16	2.45	6.40	3.40	3.86
3	2.84	2.50	5.75	2.30	3.35
4	2.95	2.70	4.55	1.65	2.96
Cultivar Mean	2.84b[x]	2.60b	5.49a	2.61b	

[z,y]Absence of a letter shows the SNK test was not carried out after the analysis of variance showed no significance, 1% level.

[x]Mean separation within row by SNK test, 1% level.

Table 28. Mean number of smooth fruit per plant of each cultivar on clusters 1 to 4.

Cluster	Cultivar				Cluster means
	CS	FB	IPB	VR	
1	1.84d[z]	2.25cd	3.95bc	2.25cd	2.58b[x]
2	2.74cd	2.15d	5.85a	2.65cd	3.35a
3	2.53cd	2.40cd	4.40b	1.55d	2.72b
4	2.63cd	2.45cd	2.30cd	1.20d	2.14b
Cultivar means	2.43b[y]	2.31b	4.12a	1.91b	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Mean separation within column by SNK test, 1% level.

Table 29. Mean number of moderately rough fruit per plant of each cultivar on clusters 1 to 4.

Cluster	Cultivar				Cluster means
	CS	FB	IPB	VR	
1	0.579bc[z]	0.450bc	1.05bc	0.750bc	0.709[x]
2	0.368bc	0.300bc	0.50bc	0.550bc	0.430
3	0.158c	0.100c	1.25b	0.550bc	0.519
4	0.210bc	0.200bc	2.00a	0.250bc	0.671
Cultivar means	0.329b[y]	0.262b	1.20a	0.525b	

[z]Mean separation within and between columns by SNK test, 1% level.

[y]Mean separation within row by SNK test, 1% level.

[x]Absence of a letter in column shows the test was not carried out after the analysis of variance showed no significance, 1% level.

moderately rough fruit number.

Number of Rough Fruit. Number of rough fruit was not significantly dependent on cultivar, although there was an indication of a possible cultivar effect at the 5% level of significance (Tables 26 and 30). Also there was an indication of the possibility of cluster X treatment interaction effects at the 5% level of significance (Tables 26 and 31). The differences among clusters and among the chilling treatments were not significant (Table 26).

At the same time that Experiment 2 was underway, some VR plants which were grown in another house and were expected to produce good quality fruits, produced a high proportion of rough fruit.

Flower Morphology and Fruit Shape. It was intended to test the relationship between flower appearance and subsequent fruit shape (Table 32); however, the proportions of flowers in the semi-normal and abnormal groups were comparatively too low to warrant a X^2 test. Nevertheless, inspection of the data showed relatively high relationships between normal flowers and smooth fruit and abnormal flowers and rough fruit (Table 32). There was no apparent relationship between semi-normal flowers and moderately rough fruit.

Experiment 3

The cool temperature regime did not have any marked effect on the production of rough fruit (Table 35).

There was a significant difference between the total fruit numbers of the 2 cultivars in the warm regime and an indication of significance

Table 30. Mean number of rough fruit per plant of each cultivar.

Cultivar	Number of rough fruit
CS	0.079[Z]
FB	0.025
IPB	0.163
VR	0.175

[Z]The SNK test was not carried out after the analysis of variance showed no significance, [illegible] 1% level.

Table 31. Mean number of rough fruit per plant of each treatment[z] group on clusters 1 to 4.

Cluster	Treatment (weeks)					Cluster Means
	3	4	5	6	Control	
1	0.312[y]	0.062	0.062	0.000	0.067	0.101[w]
2	0.312	0.062	0.000	0.000	0.000	0.076
3	0.062	0.000	0.250	0.250	0.000	0.114
4	0.000	0.250	0.250	0.188	0.067	0.152
Treatment Means	0.172[x]	0.094	0.141	0.109	0.033	

[z]Age (from seeding) at which chilling treatment was initiated.

[y,x,w]SNK tests were not carried out after the analyses of variance showed no significance , 1% level.

Table 32. Numbers of normal[z], semi-normal[y] and abnormal flowers[x] and the subsequent smooth, moderately rough and rough fruits observed.

	Normal flower	Smooth fruit	Semi-normal flower	Moderately rough fruit	Abnormal flower	Rough fruit
Number	1005.00	854.00	16.00	175.00	34.00	26.00
% of total number	95.26	80.95	1.52	16.59	3.22	2.46

[z]Normal flower expected to yield smooth fruit.

[y]Semi-normal flower expected to yield moderately rough fruit.

[x]Abnormal flower expected to yield rough fruit.

at the 5% level between the same cultivars grown under the cool regime (Tables 33 and 34). The IPB plants had more fruit than VR, and there were more fruit on both cultivars in the cool than in the warm regime (Tables 34 and 35).

The numbers of smooth fruit paralleled the results for numbers of total fruit for both cultivars in the 2 regimes (Tables 34 and 35). The numbers of moderately rough fruit showed no significant difference between cultivars (Table 33). By inspection it can be seen that there were more moderately rough fruit in the cool regime (Table 35) than in the warm (Table 34) and also that IPB had less moderately rough fruit in the warm regime, but more such fruit in the cool regime than VR.

There was no rough fruit on the plants in the warm regime (Table 34); however, under cool conditions, the difference in the number of rough fruit between cultivars is reflected in a mean square which indicates a significant difference (Table 33). IPB had a small number of rough fruit whereas VR had none (Table 35).

Table 33. Analyses of variance of the mean total, smooth, moderately rough and rough fruit numbers per plant on clusters 1 to 4.

		Mean squares[z]						
		Warm temperature regime[y,x]			Cool temperature regime[w]			
Source	Df	Total fruit	Smooth fruit	Moderately rough fruit	Total fruit	Smooth fruit	Moderately rough fruit	Rough fruit
Cultivar (C)	1	16.53**	21.12**	0.281	50.00*	7.03*	6.12	3.78*
Plants/C	6	0.74	0.96	0.156	6.50	0.61	2.06	0.62
Cluster (P)	3	11.86*	8.12	0.365	19.75	18.28*	0.75	0.36
P X C	3	1.62	1.46	0.281	3.58	8.61	1.04	0.36
Error	18	2.74	2.62	0.240	5.17	5.36	0.98	0.53
Total	31							

[z]Data for warm and cold temperature regimes analyzed separately.

[y]No rough fruit produced.

[x]Warm temperature regime: day high of $24^{o} \pm 1^{o}C$ and night low $19^{o} \pm 1^{o}C$.

[w]Cool temperature regime with a diurnal cycle from $5^{o} \pm 1^{o}C$ to $21^{o} \pm 1^{o}C$.

*Significant, 5% level.

**Significant, 1% level.

Table 34. Mean numbers of total, smooth and moderately rough fruit per plant of each cultivar on clusters 1 to 4 (warm temperature regime)[z]

Cluster	Total fruit			Smooth fruit			Moderately rough fruit		
	IPB	VR	Cluster mean	IPB	VR	Cluster mean	IPB	VR	Cluster mean
1	2.50[y]	2.25	3.38[x]	2.50[w]	1.75	2.12[v]	0.000[u]	0.500	0.250[t]
2	4.50	2.25	3.38	4.25	1.50	2.88	0.250	0.750	0.500
3	1.25	0.00	0.62	1.25	0.00	0.62	0.000	0.000	0.000
4	2.25	0.25	1.25	2.00	0.25	1.12	0.250	0.000	0.125
Cultivar means	2.62a[s]	1.19b		2.50a[r]	0.88b		0.125[q]	0.313	

[z]Day high of 24° ± 1°C and night low of 19° ± 1°C.

[y,x,w,v,u,t,q]Absence of a letter shows the SNK tests were not carried out after the analysis of variance showed no significance, 1% level.

[s,r]Mean separation within rows by SNK test, 1% level.

Table 35. Mean total, smooth, moderately rough and rough fruit per plant of each cultivar on clusters 1 to 4 (cool temperature regime)[z]

Cluster	Total fruit		Cluster mean	Smooth fruit		Cluster mean	Moderately rough fruit		Cluster mean	Rough fruit		Cluster mean
	IPB	VR		IPB	VR		IPB	VR		IPB	VR	
1	8.75[y]	4.50	6.62[x]	6.75[w]	3.00	4.88[v]	1.50[u]	1.50	1.50[t]	0.50[s]	0.00	0.25[r]
2	6.75	4.25	5.50	4.75	3.50	4.12	1.75	0.75	1.25	0.25	0.00	0.12
3	5.50	4.50	5.00	3.50	4.00	3.75	1.25	0.50	0.88	0.75	0.00	0.38
4	4.00	1.75	2.88	1.00	1.75	1.38	1.75	0.00	0.88	1.25	0.00	0.62
Cultivar means	6.25[q]	3.75		4.00[p]	3.06		1.56[m]	0.69		0.69[n]	0.00	

[z]Diurnal cycle from $5^{o} \pm 1^{o}C$ to $21^{o} \pm 1^{o}C$.

[y-n]Absence of a letter shows the SNK tests were not carried out after the analysis of variance showed no significance, 1% level.

DISCUSSION

When the number of rough fruits is compared with the total number and the number of smooth fruits produced in the field experiment (Table 7), it is seen that rough fruit production was quite substantial. These results are typical of the horticultural problem of deformed fruit in the tomato crop.

The data from the field experiment showed significant differences among different genotypes (Tables 6 and 7). IPB had the most and BB the least numbers of rough fruit. The data for their 2 reciprocal F_1 hybrids were intermediate between the parental values. Rough fruit number produced by BB and FB were similar in both clusters whereas the difference between FB and IPB was shown to be significant in cluster 2 only. The failure of the latter 2 lines to show significance in cluster 1 could be due to the relatively large variation in rough fruit number which resulted in a relatively large calculated mean square of 14.128 (Table 6). Thus,a relatively large difference was required for the 2 lines to be declared significantly different in cluster 1.

Accounts of tomato fruit malformations (other than the type investigated in this study) given by workers such as Ekstrand (10) and Salvioli and Martín (34) have indicated that these fruit abnormalities are inherited. To the casual observer, the results on rough fruit production obtained in the field experiment (Table 7) would indicate that, if indeed the character for the production of this type of misshapen fruit has a genetic base, it is partially dominant. This would then suggest that the gene or gene complex responsible for the expression of

this character is different from that which causes, for example, "catfaced" fruit. The gene, afl, which is responsible for the latter tomato fruit disorder has been described as recessive by Salvioli and Martin (34).

Inspection of the data for the 2 reciprocal F_1 hybrids (IPB X BB and BB X IPB) and their parents, indicated a possibility of the influence of maternal effects on the character in the cluster 2 data (Table 7). This should not be surprising since the fruit develops from the ovary, which is a maternal organ.

In the partially controlled environment experiments (Expt. 1a, 2 and 3), differences in the number of rough fruit produced by the different genotypes were observed (Tables 16, 30 and 35). Some of these differences were significant at the 1% level (Tables 8 and 16) whereas others only approached significance, above 1% but lower than the 5% level (Tables 26 and 33). However, these differences cannot be considered to be horticulturally important when the rough fruit numbers are compared with the total fruit numbers and the numbers of marketable (smooth and moderately rough) fruit (Tables 10, 12, 14, 27, 28, 29 and 35).

Although the type of fruit malformation studied is different from others reported by several workers, it is possible that similar external factors which influence the production of, for example, "catfaced" or "puffy" fruits, could be responsible for rough fruit. The plants for the field experiment were set out in the middle of May, a time when temperatures were relatively low. Such low temperatures have been reported to cause other fruit malformations by Kaname and Itagi (20), Knavel and Mohr (21), Saito and Ito (33), Salvioli and Martín (34), and others.

Therefore, it is likely that relatively low temperatures during the hardening and post-transplanting periods could have contributed to rough fruit production in the field. The results of the controlled experiments (Tables 8, 26 and 33), however, did not confirm this assumption nor the reports of Shoemaker (35) and Stoner (37) that relatively low temperatures caused rough fruit.

The relatively cool temperatures and periods of exposure employed in the controlled experiments were similar to those used by Kaname and Itagi (20) to produce abnormally-shaped fruit. Therefore, the practically negative results obtained in this study probably indicate that, if indeed relatively cool temperatures are responsible for rough fruit production, the low temperature requirements for this type of fruit disorder are different from those reported by Kaname and Itagi (20), Knavel and Mohr (21) and others for other fruit abnormalities. The temperatures (4.4 ^{o}-12.8 ^{o}C) employed in the growth chambers were possibly either not low enough or the plants were not exposed long enough (3 to 14 days in Experiments 1a and 2) to the chilling temperatures. It is also possible that the temperature sensitive period (6, 11, 22 and 48) was missed because the chilling treatments were initiated 26, 22 and 35 days from seeding respectively in Experiments 1a, 2 and 3.

There is the possibility that the temperature effect (if any) on rough fruit production is not so much a matter of how low the temperature is but how sharply it fluctuates. Ricada and Honnorat (28) have suggested that sharp changes in temperature which caused periodic checks in growth were the probable cause of some tomato fruit malformations in Morocco. It is likely for such sharp temperature variations to occur during

spring and early summer as a result of windy conditions and variable sunny and cloudy periods. Therefore, it is possible that sharp temperature fluctuations were responsible for the rough fruit produced in the field (Tables 6 and 7). Plants used in the controlled experiments 1a and 2 gave no indication of low temperature effect on rough fruit production (Tables 8 and 26), probably because the temperatures employed were varied gradually between the high and low levels. The cool temperature regime in Experiment 3 was intended to simulate sharp temperature fluctuations comparable to those experienced in the field but the results were not like those in the field (Tables 6, 7, 33 and 35). The chilling treatments were probably either applied too late (35 days after seeding) and/or the temperature fluctuations were not sharp enough. It is even possible that the condition of the plant prior to exposure to chilling and/or fluctuating temperatures might be the critical factor because some plants which were less vigorous than those used in the controlled environment Experiment 2 but were used as filler plants during the treatment period, produced more rough fruit than the plants used in the experiment.

The results obtained in the controlled environment studies obviously indicate that production of rough fruit by tomato plants is not simply a result of exposure to low temperature as reported by Shoemaker (35) and Stoner (37). It is likely that the rough fruit condition is caused by an interaction of low temperatures with other factors such as sunlight, humidity and nutrient and water supply, as suggested by Kaname and Itagi (20), Ricada and Honnorat (28) and Wedding and Vines (45) for the other tomato fruit shape abnormalities. The factors could interact in

the following manner to produce rough fruit. Relatively cool temperatures are expected to reduce vegetative growth, increase flower numbers, and produce fasciated flowers (18, 33, 48 and 49). The reduction in vegetative growth results in a reduced net production of photosynthates. Flower numbers are also increased with increased nutrient supply (47). Thus, if water is not limiting, under relatively cool temperature conditions and abundant nutrient supply, a lot of flowers are produced. Subsequently there would be mass fruit set (14, 18, 27, 41, 42, and 43) using the relatively limited plant reserves. According to Tokarev (40) under conditions of mass fruit production, the plant reduces the rate of fruit development. Therefore, on the basis of the ontogeny of the ovary given by Hayward (15), this could cause differential rates of growth of the different sections of the ovary resulting in non-symmetrical fruits which are largely crinkled at the stem-end and severely grooved. Photoperiod or light intensity might affect the availability of photosynthates to the developing fruits and thereby contribute to the development of rough fruit. Sharp temperature fluctuations might also influence rough fruit production by checking growth of the fruit if the observation of Ricada and Honnorat (28) can be applied to this problem.

According to Tesi and Ferlicca (39) and other workers, application of growth regulators to improve fruit set sometimes resulted in malformed fruit. Therefore, it is even possible that complex external factors could cause particular genotypes to produce endogenous growth regulators, which then act on the developmental processes of the fruit to result in rough fruit.

Apparently there are differences in the quantities or numbers of rough fruit produced on different cultivars as shown in both the field and controlled environment studies, although the quantities produced in the controlled environment experiments are not horticulturally significant. Further studies are, however, needed to develop a procedure which can be used to test given genotypes' rough fruit production and, hopefully, separate "resistant" forms from the population and then employ such lines in breeding programmes which could be expected to yield cultivars which were highly resistant to the development of malformed fruit.

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